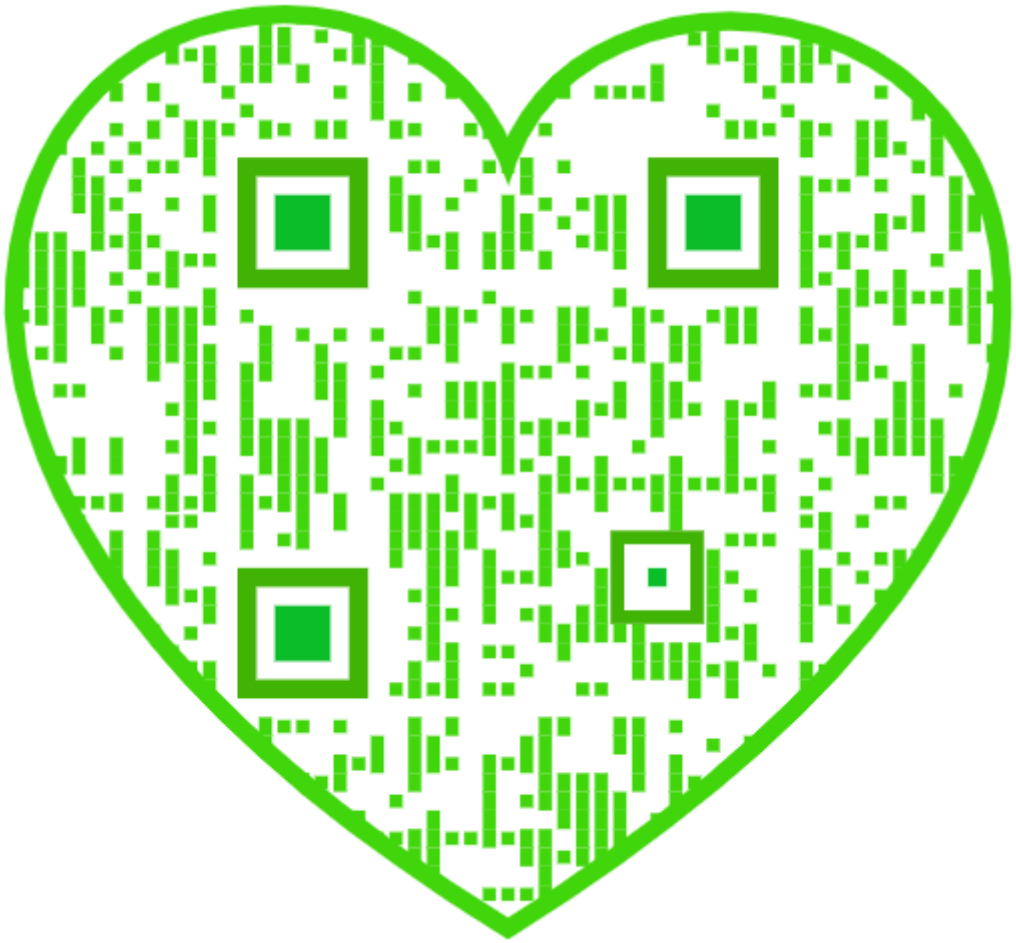

MY AIRSHIPS

ALBERTO SANTOS-DUMONT

MY AIRSHIPS

The Story of My Life

BY

ALBERTO SANTOS-DUMONT

ILLUSTRATED

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MY AIRSHIPS

INTRODUCTORY FABLE

THE REASONING OF CHILDREN

Two young Brazilian boys strolled in the shade, conversing. They were simple youths of the interior, knowing only the plenty of the primitive plantation where, undisturbed by labour-saving devices, Nature yielded man her fruits at the price of the sweat of his brow.

They were ignorant of machines to the extent that they had never seen a waggon or a wheelbarrow. Horses and oxen bore the burdens of plantation life on their backs, and placid Indian labourers wielded the spade and the hoe.

Yet they were thoughtful boys. At this moment they discussed things beyond all that they had seen or heard.

"Why not devise a better means of transport than the backs of horses and of oxen?" Luis argued. "Last summer I hitched horses to a

barn door, loaded it with sacks of maize, and hauled in one load what ten horses could not have brought on their backs. True, it required seven horses to drag it, while five men had to sit around its edges and hold the load from falling off."

"What would you have?" answered Pedro. "Nature demands compensations. You cannot get something from nothing or more from less!"

"If we could put rollers under the drag, less pulling power would be needed."

"Bah! the force saved would be used up in the labour of shifting the rollers."

"The rollers might be attached to the drag at fixed points by means of holes running through their centres," mused Luis. "Or why should not circular blocks of wood be fixed at the four corners of the drag? . . . Look, Pedro, yonder along the road. What is coming? The very thing I imagined, only better! One horse is pulling it at a good trot!"

The first waggon to appear in that region of the interior stopped, and its driver spoke with the boys.

"These round things?" he answered to their questions; "they are called wheels."

Pedro accepted his explanation of the principle slowly.

"There must be some hidden defect in the device," he insisted. "Look around us. Nowhere does Nature employ the device you call the wheel. Observe the mechanism of the human body; observe the horse's frame; observe . . ."

"Observe that horse and man and waggon with its wheels are speeding from us," replied Luis, laughing. "Cannot you yield to accomplished facts? You tire me with your appeals to Nature. Has man ever accomplished anything worth having except by combating Nature? We do violence to her when we chop down a tree! I would go further than this invention of the waggon. Conceive a more powerful motive force than that horse. . . ."

"Attach two horses to the waggon."

"I mean a machine," said Luis.

"A mechanical horse with powerful iron legs!" suggested Pedro.

"No; I would have a motor waggon. If I could find an artificial force I would cause it to act on a point in the circumference of each wheel. Then the waggon could carry its own puller!"

"You might as well attempt to lift yourself

from the ground by pulling at your boot straps!" laughed Pedro. "Listen, Luis. Man is subject to certain natural laws. The horse, it is true, carries more than his own weight, but by a device of Nature's own—his legs. Had you the artificial force you dream of you would have to apply it naturally. I have it! It would have to be applied to poles to push your waggon from behind!"

"I hold to applying the force to the wheels," insisted Luis.

"By the nature of things you would lose power," said Pedro. "A wheel is harder to force on from a point inside its circumference than when the motive power is applied to that circumference directly, as by pushing or pulling the waggon."

"To relieve friction I would run my power waggon on smooth iron rails, then the loss in power would be gained in speed."

"Smooth iron rails!" laughed Pedro. "Why, the wheels would slip on them. You would have to put notches all round their circumference and corresponding notches in the rails. And what would there be to prevent the power waggon slipping off the rails even then?"

The boys had been walking briskly. Now a

shrieking noise startled them. Before them stretched in long lines a railway in course of construction, and from among the hills came toward them, at what seemed immense speed, a construction train.

"It is an avalanche!" cried Pedro.

"It is the very thing that I was dreaming of!" said Luis.

The train stopped. A gang of labourers emerged from it and began working on the road-bed, while the locomotive engineer answered the boys' questions and explained the mechanism of his engine. The boys discussed this later wonder as they wended their way homeward.

"Could it be adapted to the river men might become lords of the water as of the land," said Luis. "It would be only necessary to devise wheels capable of taking hold of the water. Fix them to a great frame like that waggon body and the steam-engine could propel it along the surface of the river!"

"Now you talk folly," exclaimed Pedro. "Does a fish float on the surface? In the water we must travel as the fish does—in it, not over it! Your waggon body, being filled with light air, would upset at your first movement. And your wheels—

do you imagine they would take hold of so liquid a thing as water?"

"What would you suggest?"

"I would suggest that your water waggon be jointed in half-a-dozen places, so that it could be made to squirm through the water like a fish. Listen! A fish navigates the water. You desire to navigate the water. Then study the fish! There are fish that use propeller fins and flippers too. So you might devise broad boards to strike the water, as our hands and feet strike it in swimming. But do not talk about waggon wheels in the water!"

They were now beside the broad river. The first steamer to navigate it was seen approaching from the distance. The boys could not yet well distinguish it.

"It is evidently a whale," said Pedro. "What navigates the water? Fish. What is the fish that sometimes is seen swimming with its body half way above the surface? The whale. See, it is spouting water!"

"That is not water, but steam or smoke," said Luis.

"Then it is a dead whale, and the steam is the vapour of putrefaction. That is why it stays

so high in the water—a dead whale rises high on its back!"

"No," said Luis; "it is really a steam water waggon."

"With smoke coming from fire in it, as from the locomotive?"

"Yes."

"But the fire would burn it up. . . ."

"The body is doubtless iron, like the locomotive."

"Iron would sink. Throw your hatchet in the river and see."

The steam-boat came to shore, close to the boys. Running to it, to their joy, they perceived on its deck an old friend of their family, a neighbouring planter.

"Come, boys!" he said, "and I will show you round this steam-boat."

After a long inspection of the machinery the two boys sat with their old friend on the fore-deck in the shade of an awning.

"Pedro," said Luis, "will not men some day invent a ship to sail in the sky?"

The common-sense old planter glanced with apprehension at the youth's face, flushed with ardour.

"Have you been much in the sun, Luis?" he asked.

"Oh, he is always talking in that flighty way," Pedro reassured him. "He takes pleasure in it."

"No, my boy," said the planter; "man will never navigate a ship in the sky."

"But on St John's Eve, when we all make bonfires, we also send up little tissue-paper spheres with hot air in them," insisted Luis. "If we could construct a very great one, big enough to lift a man, a light car, and a motor, might not the whole system be propelled through the air, as a steam-boat is propelled through the water?"

"Boys, never talk foolishness!" exclaimed the old friend of the family hurriedly as the captain of the boat approached. It was too late. The captain had heard the boy's observation; instead of calling it folly he excused him.

"The great balloon which you imagine has existed since 1783," he said; "but, though capable of carrying a man or several men, it cannot be controlled — it is at the mercy of the slightest breeze. As long ago as 1852 a French engineer named Giffard made a brilliant failure with what he called a 'dirigible balloon,' furnished with the motor and propeller Luis has dreamed

of. All he did was to demonstrate the impossibility of directing a balloon through the air."

"The only way would be to build a flying machine on the model of the bird," spoke up Pedro with authority.

"Pedro is a very sensible boy," observed the old planter. "It is a pity Luis is not more like him and less visionary, Tell me, Pedro, how did you come to decide in favour of the bird as against the balloon?"

"Easily," replied Pedro glibly. "It is the most ordinary-common sense. Does man fly? No. Does the bird fly? Yes. Then if man would fly let him imitate the bird. Nature has made the bird, and Nature never goes wrong. Had the bird been furnished with a great air bag I might have suggested a balloon."

"Exactly!" exclaimed both captain and planter.

But Luis, sitting in his corner, muttered, unconvinced as Galileo: "It will move!"

CHAPTER I

THE COFFEE PLANTATION

FROM the way in which the partisans of Nature have fallen on me I might well be the uninformed and visionary Luis of the fable, for has it not been taken for granted that I began my experiments ignorant alike of mechanics and ballooning? And before my experiments succeeded, were they not all called impossible?

Does not the final condemnation of the common-sense Pedro continue to weigh on me?

After steering my ship through the sky at will I am still told that flying creatures are heavier than the air. A little more and I should be made responsible for the tragic accidents of others who had not my experience of mechanics and aeronautics.

On the whole, therefore, I think it is best to begin at the coffee plantation where I was born in the year 1873.

Inhabitants of Europe comically figure those

PLANTATION RAILWAY
SANTOS-DUMONT COFFEE PLANTATION IN BRAZIL

Brazilian plantations to themselves as primitive stations of the boundless pampas, as innocent of the cart and the wheelbarrow as of the electric light and the telephone. There are such stations far in the interior. I have been through them on hunting trips, but they are not the coffee plantations of Sao-Paulo.

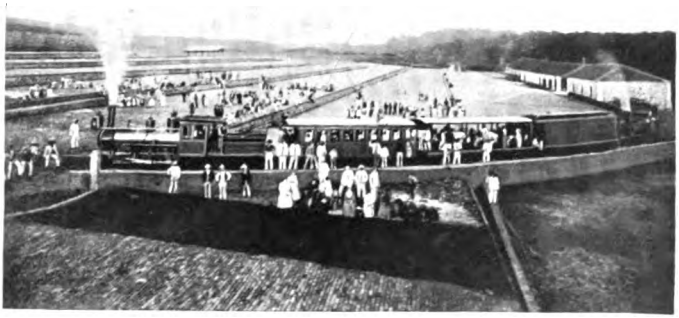
I can hardly imagine a more stimulating environment for a boy dreaming over mechanical inventions. At the age of seven I was permitted to drive our "locomobiles" of the epoch—steam traction-engines of the fields with great broad wheels. At the age of twelve I had conquered my place in the cabs of the Baldwin locomotive engines hauling train-loads of green coffee over the sixty miles of our plantation railway. When my father and brothers would take pleasure in making horseback trips far and near, to see if the trees were clean, if the crops were coming up, if the rains had done damage, I preferred to slip down to the Works and play with the coffee-engines.

I think it is not generally understood how scientifically a Brazilian coffee plantation may be operated. From the moment when a railway train has brought the green berries to the Works to

the moment when the finished and assorted product is loaded on the transatlantic ships, no human hand touches the coffee.

You know that the berries of black coffee are red when they are green. Though it may complicate the statement, they look like cherries. Car loads of them are unloaded at the central works and thrown into great tanks, where the water is continually renewed and agitated. Mud that has clung to the berries from the rains, and little stones which have got mixed up with them in the loading of the cars, go to the bottom, while the berries and the little sticks and bits of leaves float on the surface and are carried from the tank by means of an inclined trough, whose bottom is pierced with innumerable little holes. Through these holes falls some of the water with the berries, while the little sticks and pieces of leaves float on.

The fallen coffee berries are now clean. They are still red, about the size and look of cherries. The red exterior is a hard pod or *polpa*. Inside of each pod are two beans, each of which is covered with a skin of its own. The water which has fallen with the berries carries them on to the machine called the *despolpador*, which



THE WORKS

"LOCOMOBILE

THE SANTOS-DUMONT COFFEE PLANTATION IN BRAZIL

breaks the outside pod and frees the beans. Long tubes, called "dryers," now receive the beans, still wet, and with their skins still on them. In these dryers the beans are continually agitated in hot air.

Coffee is very delicate. It must be handled delicately. Therefore the dried beans are lifted by the cups of an endless-chain elevator to a height, whence they slide down an inclined trough to another building because of the danger of fire. This is the coffee machine house.

The first machine is a ventilator, in which sieves, shaken back and forth, are so combined that only the coffee beans can pass through them. No coffee is lost in them and no dirt is kept by them, for one little stone or stick that may still have been carried with the beans would be enough to break the next machine.

Another endless-chain elevator carries the beans to a height, whence they fall through an inclined trough into this *descascador* or "skinner." It is a highly delicate machine; if the spaces between are a trifle too big the coffee passes without being skinned, while if they are too small they break the beans.

Another elevator carries the skinned beans with

their skins to another ventilator, in which the skins are blown away.

Still another elevator takes the now clean beans up and throws them into the "separator," a great copper tube two yards in diameter and about seven yards long, resting at a slight incline. Through the separator tube the coffee slides. As it is pierced at first with little holes the smaller beans fall through them. Farther along it is pierced with larger holes, and through these the medium-sized beans fall, and still farther along are still larger holes, for the large round beans called "Moka."

The machine is a separator because it separates the beans into their conventional grades by size. Each grade falls into its hopper, beneath which are stationed weighing scales and men with coffee sacks. As the sacks fill up to the required weight they are replaced by empty ones, and the tied and labelled sacks are shipped to Europe.

As a boy I played with this machinery and the driving engines that furnished its motive force, and before long familiarity had taught me how to repair any part of it. As I have said, it is delicate machinery. In particular, the moving sieves would be continually getting out

of order. While they were not heavy, they moved back and forth horizontally at great speed and took an enormous amount of motive power. The belts were always being changed, and I remember the fruitless efforts of all of us to remedy the mechanical defects of the device.

Now is it not curious that those troublesome shifting sieves were the only machines at the coffee works that were not rotary? They were not rotary, and they were bad. I think this put me as a boy against all *agitating* devices in mechanics and in favour of the more easily-handled and more serviceable rotary movement.

It may be that half-a-century from now man will assume mastery of the air by means of flying machines heavier than the medium in which they move. I look forward to the time with hope, and at the present moment I have gone further to meet it than any other, because my own air-ships (which have been so reproached on this head) are slightly heavier than the air. But I am prejudiced enough to think that when the time comes the conquering device will not be flapping wings or any substitute of an agitating nature.

I cannot say at what age I made my first kites, but I remember how my comrades used to tease

me at our game of "Pigeon flies!" All the children gather round a table, and the leader calls out: "Pigeon flies!" "Hen flies!" "Crow flies!" "Bee flies!" and so on, and at each call we were supposed to raise our fingers. Sometimes, however, he would call out "Dog flies!" "Fox flies!" or some other like impossibility, to catch us. If anyone raised a finger he was made to pay a forfeit. Now my playmates never failed to wink and smile mockingly at me when one of them called "Man flies!" for at the word I would always lift my finger very high, as a sign of absolute conviction, and I refused with energy to pay the forfeit.

Among the thousands of letters which I received after winning the Deutsch prize there was one that gave me particular pleasure. I quote from it as a matter of curiosity:

". . . Do you remember the time, my dear Alberto, when we played together 'Pigeon flies!'? It came back to me suddenly the day when the news of your success reached Rio.

"'Man flies!' old fellow! You were right to raise your finger, and you have just proved it by flying round the Eiffel Tower.

"You were right not to pay the forfeit; it is M. Deutsch who has paid it in your stead. Bravo! you well deserve the 100,000 franc prize.

"They play the old game now more than ever at home, but the name has been changed and the rules modified—since October 19, 1901. They call it now 'Man flies!' and he who does not raise his finger at the word pays his forfeit.—Your friend, PEDRO."

This letter brings back to me the happiest days of my life, when I exercised myself in making light aeroplanes with bits of straw, moved by screw propellers driven by springs of twisted rubber, or ephemeral silk-paper balloons. Each year, on June 24th, over the St John bonfires, which are customary in Brazil from long tradition, I inflated whole fleets of these little Montgolfiers, and watched in ecstasy their ascension to the skies.

In those days, I confess, my favourite author was Jules Verne. The wholesome imagination of this truly great writer, working magically with the immutable laws of matter, fascinated me from childhood. In its daring conceptions I saw, never

doubting, the mechanics and the science of the coming ages, when man should by his unaided genius rise to the height of a demigod.

With Captain Nemo and his shipwrecked guests I explored the depths of the sea in that first of all submarines, the *Nautilus*. With Phineas Fogg I went round the world in eighty days. In "Screw Island" and "The Steam House" my boyish faith leaped out to welcome the ultimate triumphs of an automobilism that in those days had not as yet a name. With Hector Servadoc I navigated the air.

I saw my first balloon in 1888, when I was about fifteen years old. There was a fair or celebration of some sort at the town of Sao-Paulo, and a professional made the ascent, letting himself down afterwards in a parachute. By this time I was perfectly familiar with the history of Montgolfier and the balloon craze, which, following on his courageous and brilliant experiments, so significantly marked the last years of the eighteenth, and the first years of the nineteenth, centuries. In my heart I had an admiring worship for the four men of genius—Montgolfier, and the physicist, Charles, and Pilâtre de Rozier, and the engineer, Henry Giffard—who have attached their

names for ever to great steps forward in aerial navigation.

I, too, desired to go ballooning. In the long, sun-bathed Brazilian afternoons, when the hum of insects, punctuated by the far-off cry of some bird, lulled me, I would lie in the shade of the verandah and gaze into the fair sky of Brazil, where the birds fly so high and soar with such ease on their great outstretched wings, where the clouds mount so gaily in the pure light of day, and you have only to raise your eyes to fall in love with space and freedom. So, musing on the exploration of the vast aerial ocean, I, too, devised air-ships and flying machines in my imagination.

These imaginations I kept to myself. In those days, in Brazil, to talk of inventing a flying machine or dirigible balloon would have been to mark oneself off as unbalanced and visionary. Spherical balloonists were looked on as daring professionals, not differing greatly from acrobats; and for the son of a planter to dream of emulating them would have been almost a social sin.

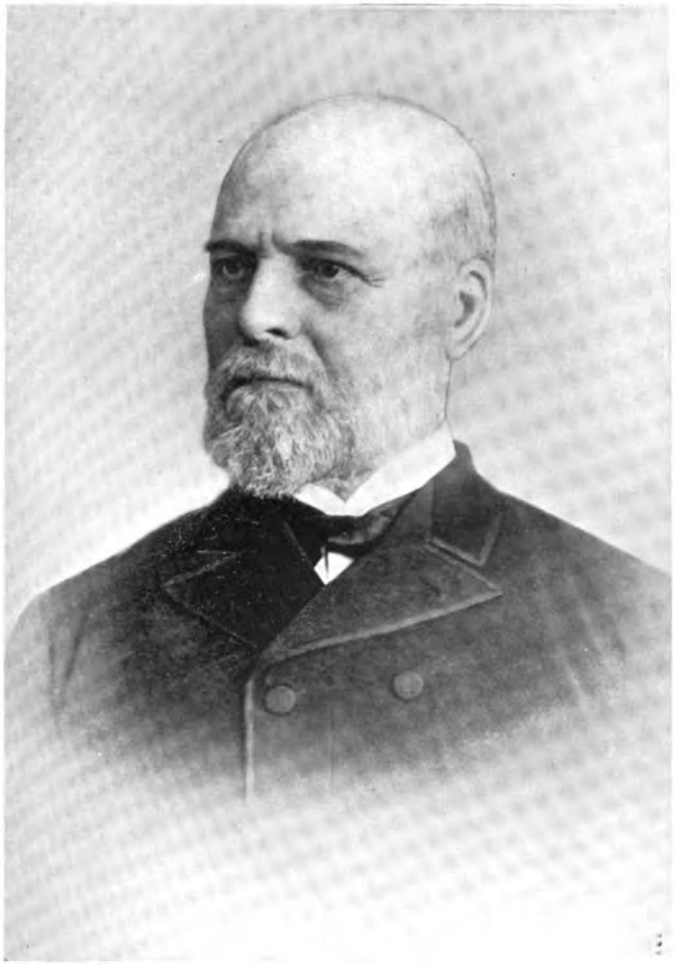
CHAPTER II

PARIS—PROFESSIONAL BALLOONISTS—AUTOMOBILES

In 1891 it was decided that our family should make a trip to Paris, and I rejoiced doubly at the prospect. All good Americans are said to go to Paris when they die. But to me, with the bias of my reading, France—the land of my father's ancestors and of his own education as an engineer at the École Centrale—represented everything that is powerful and progressive.

In France the first hydrogen balloon had been let loose and the first air-ship had been made to navigate the air with its steam-engine, screw propeller, and rudder. Naturally I figured to myself that the problem had made marked progress since Henry Giffard in 1852, with a courage equal to his science, gave his masterly demonstration of the problem of directing balloons.

I said to myself: "I am going to Paris to see the new things—steerable balloons and automobiles!"



HENRIQUES SANTOS-DUMONT
FATHER OF A. SANTOS-DUMONT AND FOUNDER OF THE COFFEE PLANTATIONS IN BRAZIL

On one of my first free afternoons, therefore, I slipped away from the family on a tour of exploration. To my immense astonishment I learned that there were no steerable balloons—that there were only spherical balloons, like that of Charles in 1783! In fact, no one had continued the trials of an elongated balloon driven by a thermic motor begun by Henry Giffard. The trials of such balloons with an electric motor, undertaken by the Tissandier brothers in 1883, had been repeated by two constructors in the following year, but had been finally given up in 1885. For years no "cigar-shaped" balloon had been seen in the air.

This threw me back on spherical ballooning. Consulting the Paris city directory I had noted the address of a professional aeronaut. To him I explained my desires.

"You want to make an ascent?" he asked gravely. "Hum! hum! Are you sure you have the courage? A balloon ascent is no small thing, and you seem too young."

I assured him both of my purpose and my courage. Little by little he yielded to my arguments. Finally he consented to take me "for a short ascent." It must be on a calm,

sunny afternoon, and not last more than two hours.

"My honorarium will be 1200 francs," he added, "and you must sign me a contract to hold yourself responsible for all damages we may do to your own life and limbs and to mine, to the property of third parties, and to the balloon and its accessories. Furthermore, you agree to pay out railway fares and transportation for the balloon and its basket back to Paris from the point at which we come to the ground."

I asked time for reflection. To a youth eighteen years of age 1200 francs was a large sum. How could I justify the spending of it to my parents? Then I reflected:

"If I risk 1200 francs for an afternoon's pleasure I shall find it either good or bad. If it is bad the money will be lost. If it is good I shall want to repeat it and I shall not have the means."

This decided me. Regretfully I gave up ballooning and took refuge in automobiling.

Automobiles were still rare in Paris in 1891, and I had to go to the works at Valentigny to buy my first machine, a Peugeot three-and-a-half horse-power roadster.

It was a curiosity. In those days there were no automobile licenses, no "chauffeurs'" examinations. We drove our new inventions through the streets of the capital at our own risks and perils. Such was the curiosity they aroused that I was not allowed to stop in public places like the Place de l'Opéra for fear of attracting multitudes and obstructing traffic.

Immediately I became an enthusiastic automobilist. I took pleasure in understanding the parts and their proper interworking; I learned to care for my machine and to repair it; and when, at the end of some seven months, our whole family returned to Brazil I took the Peugeot roadster with me.

Returning to Paris in 1892, with the balloon idea still obsessing me, I looked up a number of other professional aeronauts. Like the first, all wanted extravagant sums to take me up with them on the most trivial kind of ascent. All took the same attitude. They made a danger and a difficulty of ballooning, enlarging on its risks to life and property. Even in presence of the great prices they proposed to charge me they did not encourage me to close with them. Obviously they were determined to keep ballooning to them-

selves as a professional mystery. Therefore I bought a new automobile.

I should add that this condition of things has changed wonderfully since the foundation of the Paris Aéro Club.

Automobile tricycles were just then coming to the fore. I chose one, and rejoiced in its freedom from breakdowns. In my new enthusiasm for the type, I was the first to introduce motor-tricycle races in Paris. Renting the bicycle track of the Parc des Princes for an afternoon I organised the race and offered the prizes. "Common-sense" people declared that the event would end disastrously; they proved to their own satisfaction that the tricycles, going round the short curves of a bicycle track, would overturn and wreck themselves. If they did not do this the inclination would certainly cause the carburator to stop or not to work so well, and the stoppage of the carburator round the sharp curve would upset the tricycles. The directors of the Vélodrome, while accepting my money, refused to let me have the track for a Sunday afternoon, fearing a fiasco! They were disappointed when the race proved to be a great success.

Returning again to Brazil I regretted bitterly

that I had not persevered in my attempt to make a balloon ascent. At that distance, far from ballooning possibilities, even the high prices demanded by the aeronauts seemed to me of secondary importance. Finally, one day in 1897, in a Rio book-shop, when making my purchases of reading matter for a new voyage to Paris, I came on a volume of MM. Lachambre and Machuron, "Andrée—Au Pôle Nord en Ballon."

The reading of this book during the long sea voyage proved a revelation to me, and I finished by studying it like a text-book. Its description of materials and prices opened my eyes. At last I saw clearly. Andrée's immense balloon—a reproduction of whose photograph on the book cover showed how those who gave it the final varnishing climbed up its sides and over its summit like a mountain—cost only 40,000 francs to fully construct and equip!

I determined that on arriving in Paris I would cease consulting professional aeronauts and would make the acquaintance of constructors.

I was particularly anxious to meet M. Lachambre, the builder of the Andrée balloon, and M. Machuron, who was his associate and the writer of the book. In these men I will say frankly that I found all

I had hoped for. When I asked M. Lachambre how much it would cost me to take a short trip in one of his balloons his reply so astonished me that I asked him to repeat it.

"For a long trip of three or four hours," he said, "it will cost you 250 francs, all expenses and return of balloon by rail included."

"And the damages?" I asked.

"We shall not do any damage!" he replied, laughing.

I closed with him on the spot, and M. Machuron agreed to take me up the next day.

CHAPTER III

MY FIRST BALLOON ASCENT

I HAVE kept the clearest remembrance of the delightful sensations I experienced in this my first trial in the air. I arrived early at the Parc d'Aerostation of Vaugirard so as to lose nothing of the preparations.

The balloon, of a capacity of 750 cubic metres, was lying a flat mass on the grass. At a signal from M. Lachambre the workmen turned on the gas, and soon the formless thing rounded up into a great sphere and rose into the air.

At 11 A.M. all was ready. The basket rocked prettily beneath the balloon, which a mild, fresh breeze was caressing. Impatient to be off, I stood in my corner of the narrow wicker basket with a bag of ballast in my hand. In the other corner M. Machuron gave the word: "Let go all!"

Suddenly the wind ceased. The air seemed motionless around us. We were off, going at the speed of the air current in which we now lived

and moved. Indeed, for us, there was no more wind; and this is the first great fact of all spherical ballooning. Infinitely gentle is this unfelt movement forward and upward. The illusion is complete: it seems not to be the balloon that moves but the earth that sinks down and away.

At the bottom of the abyss, which already opened 1500 yards below us, the earth, instead of appearing round like a ball, shows concave like a bowl by a peculiar phenomenon of refraction whose effect is to lift up constantly to the aeronaut's eyes the circle of the horizon.

Villages and woods, meadows and chateaux, pass across the moving scene, out of which the whistling of locomotives throws sharp notes. These faint, piercing sounds, together with the yelping and barking of dogs, are the only noises that reach one through the depths of the upper air. The human voice cannot mount up into these boundless solitudes. Human beings look like ants along the white lines that are highways, and the rows of houses look like children's playthings.

While my gaze was still held fascinated on the scene a cloud passed before the sun. Its shadow cooled the gas in the balloon, which wrinkled and began descending, gently at first, and then with

accelerated speed, against which we strove by throwing out ballast. This is the second great fact of spherical ballooning—we are masters of our altitude by the possession of a few pounds of sand!

Regaining our equilibrium above a plateau of clouds at about 3000 yards we enjoyed a wonderful sight. The sun cast the shadow of the balloon on this screen of dazzling whiteness, while our own profiles, magnified to giant size, appeared in the centre of a triple rainbow! As we could no longer see the earth all sensation of movement ceased. We might be going at storm speed and not know it. We could not even know the direction we were taking save by descending below the clouds to regain our bearings.

A joyous peal of bells mounted up to us. It was the noonday Angelus ringing from some village belfry. I had brought up with us a substantial lunch of hard-boiled eggs, cold roast beef and chicken, cheese, ice-cream, fruits and cakes, champagne, coffee, and Chartreuse. Nothing is more delicious than lunching like this above the clouds in a spherical balloon. No dining-room can be so marvellous in its decoration. The sun sets the clouds in ebullition, making them throw

up rainbow jets of frozen vapour like great sheaves of fireworks all around the table. Lovely white spangles of the most delicate ice formation scatter here and there by magic; while flakes of snow form, moment by moment, out of nothingness, beneath our very eyes, and in our very drinking-glasses.

I was finishing my little glass of liqueur when the curtain suddenly fell on this wonderful stage setting of sunlight, cloud billows, and azure. The barometer rose rapidly 5 millimetres, showing a sudden rupture of equilibrium and a swift descent. Probably the balloon had become loaded down with several pounds of snow, and it was falling into a cloud.

We passed into the half darkness of the fog. We could still see our basket, our instruments, and the parts of the rigging nearest us, but the netting that held us to the balloon was visible only to a certain height, and the balloon itself had completely disappeared. So we had for a moment the strange and delightful sensation of hanging in the void without support, of having lost our last ounce of weight in a limbo of nothingness, sombre and portentous.

After a few minutes of fall, slackened by throwing out more ballast, we found ourselves under

the clouds at a distance of about 800 yards from the ground. A village fled away from us below. We took our bearings with the compass, and compared our route map with the immense natural map that unfolded below. Soon we could identify roads, railways, villages, and forests, all hastening toward us from the horizon with the swiftness of the wind itself.

The storm which had sent us downward marked a change of weather. Now little gusts began to push the balloon from right to left, up and down. From time to time the guide rope—a great rope dangling 100 yards below our basket—would touch earth, and soon the basket, too, began to graze the tops of trees.

What is called "guide-roping" thus began for me under conditions peculiarly instructive. We had a sack of ballast at hand, and when some special obstacle rose in our path, like a tree or a house, we threw out a few handfuls of sand to leap up and pass over it. More than 50 yards of the guide rope dragged behind us on the ground; and this was more than enough to keep our equilibrium under the altitude of 100 yards, above which we decided not to rise for the rest of the trip.

This first ascent allowed me to appreciate fully the utility of this simple part of the spherical balloon's rigging, without which its landing would usually present grave difficulties. When, for one reason or another — humidity gathering on the surface of the balloon, a downward stroke of wind, accidental loss of gas, or, more frequently, the passing of a cloud before the face of the sun— the balloon came back to earth with disquieting speed, the guide rope would come to rest in part on the ground, and so, unballasting the whole system by so much of its weight, stopped, or at least eased, the fall. Under contrary conditions any too rapid upward tendency of the balloon was counterbalanced by the lifting of the guide rope off the ground, so that a little more of its weight became added to the weight of the floating system of the moment before.

Like all human devices, however, the guide rope, along with its advantages, has its inconveniences. Its rubbing along the uneven surfaces of the ground—over fields and meadows, hills and valleys, roads and houses, hedges and telegraph wires—gives violent shocks to the balloon. Or it may happen that the guide rope, rapidly unravelling the snarl in which it has twisted itself,

catches hold of some asperity of the surface or winds itself around the trunk or branches of a tree. Such an incident was alone lacking to complete my instruction.

As we passed a little group of trees a shock stronger than any hitherto felt threw us backward in the basket. The balloon had stopped short, and was swaying in the wind gusts at the end of its guide rope, which had curled itself around the head of an oak. For a quarter of an hour it kept us shaking like a salad-basket, and it was only by throwing out a quantity of ballast that we finally got ourselves loose. The lightened balloon made a tremendous leap upward and pierced the clouds like a cannon-ball. Indeed, it threatened to reach dangerous heights, considering the little ballast we had remaining in store for use in descending. It was time to have recourse to effective means, to open the manœuvre valve and let out a portion of our gas.

It was the work of a moment. The balloon began descending to earth again, and soon the guide rope again rested on the ground. There was nothing to do but to bring the trip to an end, because only a few handfuls of sand remained to us.

He who wishes to navigate an air-ship should first practise a good many landings in a spherical balloon—that is, if he wishes to land without breaking balloon, keel, motor, rudder, propeller, water-ballast cylinders, and fuel holders. The wind being rather strong, it was necessary to seek shelter for this last manœuvre. At the end of the plain a corner of the forest of Fontainebleau was hurrying toward us. In a few moments we had turned the extremity of the wood, sacrificing our last handful of ballast. The trees now protected us from the violence of the wind, and we cast anchor, at the same time opening wide the emergency valve for the wholesale escape of the gas.

The twofold manœuvre landed us without the least dragging. We set foot on solid ground, and stood there watching the balloon die. Stretched out in the field, it was losing the remains of its gas in convulsive agitations, like a great bird that dies in beating its wings.

After taking a dozen instantaneous photographs of the dying balloon we folded it and packed it in the basket with its netting folded alongside. The little chosen corner in which we had landed formed part of the grounds of the Chateau de la

Ferrière, belonging to M. Alphonse de Rothschild. Labourers from a neighbouring field were sent for a conveyance to the village of La Ferrière itself, and half-an-hour later a brake came. Putting everything into it we set off to the railway station, which was some 4 kilometres (2½ miles) distant. There we had some work to lift the basket with its contents to the ground, as it weighed 200 kilogrammes (440 pounds). At 6.30 we were back at Paris, after a journey of 100 kilometres (more than 60 miles), and nearly two hours passed in the air.

CHAPTER IV

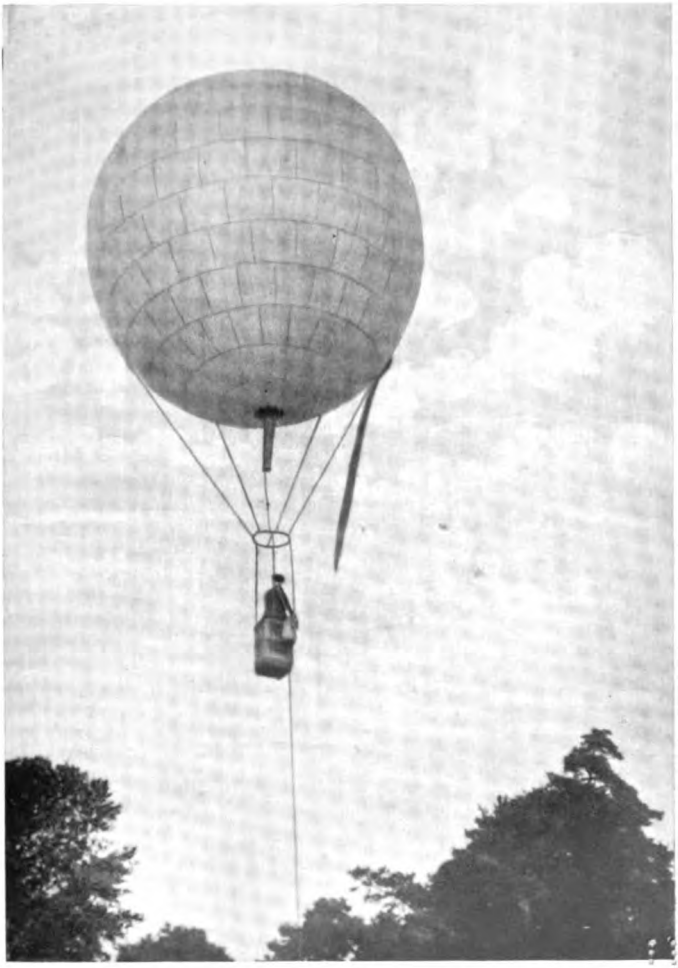
MY "BRAZIL"—SMALLEST OF SPHERICAL BALLOONS

I LIKED ballooning so much that, coming back from my first trip with M. Machuron, I told him that I wanted a balloon built for myself. He liked the idea. He thought that I wanted an ordinary-sized spherical balloon, between 500 and 2000 cubic metres in volume. No one would think of making one smaller.

It is only a short time ago, but it is curious how constructors still clung to heavy materials. The smallest balloon basket had to weigh 30 kilogrammes (66 lbs.). Nothing was light—neither envelope, rigging, nor accessories.

I gave M. Machuron my ideas. He cried out against it when I told him I wanted a balloon of the lightest and toughest Japanese silk, 100 cubic metres (about 3500 cubic feet) in volume. At the works both he and M. Lachambre tried to prove to me that the thing was impossible.

How often have things been proved to me



"THE BRAZIL"
SMALLEST OF SPHERICAL BALLOONS

impossible! Now I am used to it I expect it. But in those days it troubled me. Still I persevered.

They showed me that for a balloon to have "stability" it must have a certain weight. Again, a balloon of 100 cubic metres, they said, would be affected by the movements of the aeronaut in his basket much more than a large balloon of regulation size.

With a large balloon the centre of gravity

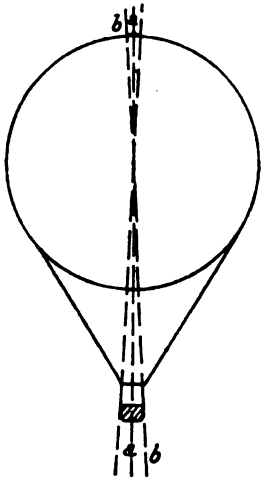


Fig. 1.

Fig. 2.

in the weight of the aeronaut is as in Fig. 1, *a*. When the aeronaut moves, say, to the right

in his basket, Fig. 1, *b*, the centre of gravity of the whole system is not shifted appreciably.

In a very small balloon the centre of gravity, Fig. 2, *a*, is undisturbed only so long as the aeronaut sits straight in the centre of his basket. When he moves to the right the centre of gravity, Fig. 2, *b*, is shifted beyond the vertical line of the balloon's circumference, causing the balloon to swing in the same direction.

Therefore, they said, your necessary movements in the basket will cause your little balloon to roll and swing continually.

"We shall make the suspension tackle longer in proportion," I replied. It was done, and the "Brazil" proved remarkably stable.

When I brought my light Japanese silk to M. Lachambre he looked at it and said: "It will be too weak." But when we came to try it with the dynamometer it surprised us. Tested thus, Chinese silk stands over 1000 kilogrammes (or 2200 lbs.) strain to the linear metre (3·3 feet). The thin Japanese silk stood a strain of 700 kilogrammes (1540 lbs.)—that is, it proved to be thirty times stronger than necessary according to the theory of strains. This is astonishing when you consider that it weighs only 80 grammes (a little

more than one ounce) per square metre. To show how experts may be mistaken in their merely off-hand judgments I have been building my air-ship balloons of this same material; yet the inside pressure they have to stand is enormous, while all spherical balloons have a great hole in the bottom to relieve it.

As the proportions finally adopted for the "Brazil" were 113 cubic metres (4104 cubic feet), corresponding to about 113 square metres (135 square yards) of silk surface, the whole envelope weighed scarcely 3½ kilogrammes (less than 8 lbs.). But the weight of the varnish, three coats, brought it up to 14 kilogrammes (about 31 lbs.). The net, which often weighs into the hundreds of lbs., weighed 1800 grammes, or nearly 4 lbs. The basket, which usually weighs 30 kilogrammes (66 lbs.) at a minimum, weighed 6 kilogrammes (13 lbs.); the basket which I now have with my little "No. 9" weighs less than 5 kilogrammes (11 lbs.). My guide rope, small, but very long—100 yards — weighed at most 8 kilogrammes (17½ lbs.); its length gave the "Brazil" a good spring. Instead of an anchor I put in a little grappling-iron of 3 kilogrammes (6½ lbs.).

Making everything light in this way I found

that, in spite of the smallness of the balloon, it would have ascensional force to take up my own weight of 50 kilogrammes (110 lbs.) and 30 kilogrammes (66 lbs.) of ballast. As a fact, I took up that amount on my first trip. On another occasion, when a French Cabinet Minister was present, anxious to see the smallest spherical balloon ever made, I had practically no ballast at all, only 4 or 5 kilogrammes (10 or 11 lbs.). Nevertheless, causing the balloon to be weighed, I went up, and made a good ascent.

The "Brazil" was very handy in the air—easy to control. It was easy to pack also on descending, and the story that I carried it in a valise is true.

Before starting out in my little "Brazil" I made from twenty-five to thirty ascents in ordinary spherical balloons, quite alone, as my own captain and sole passenger. M. Lachambre had many public ascents, and allowed me to do some of them for him. Thus I made ascents in many parts of France and Belgium. As I got the pleasure and the experience, and as I saved him the labour and paid all my own expenses and damages, it was a mutually advantageous arrangement.

I do not believe that, without such previous study and experience with a spherical balloon, a man can be capable of succeeding with an elongated dirigible balloon, whose handling is so much more delicate. Before attempting to direct an air-ship it is necessary to have learned in an ordinary balloon the conditions of the atmospheric medium, to have become acquainted with the caprices of the wind, and to have gone thoroughly into the difficulties of the ballast problem from the triple point of view of starting, of equilibrium in the air, and of landing at the end of the trip.

To have been oneself the captain of an ordinary balloon at the very least a dozen times seems to me an indispensable preliminary to acquiring an exact notion of the requisites for constructing and handling an elongated balloon furnished with its motor and propeller.

Naturally, I am filled with amazement when I see inventors, who have never set a foot in the basket, drawing up on paper—and even executing in whole or in part—fantastic air-ships, whose balloons are to have a capacity of thousands of cubic metres, loaded down with enormous motors which they do not succeed in raising from the ground, and furnished with machinery so com-

plicated that nothing works! Such inventors are afraid of nothing, because they have no idea of the difficulties of the problem. Had they previously journeyed through the air at the wind's will, and amid all the disturbing influences of atmospheric phenomena, they would understand that a dirigible balloon, to be practical, requires first of all to have the utmost extreme of simplicity in all its mechanism.

Some of the unhappy constructors who have paid with their lives the forfeit of their rashness had never made a single responsible ascent as captain of a spherical balloon! And the majority of their emulators, now so devotedly labouring, are in the same inexperienced condition. This is my explanation of their lack of success. They are in the condition in which the first-comer would find himself were he to agree to build and steer a transatlantic liner without having ever quitted land or set foot in a boat!

CHAPTER V

THE REAL AND THE IMAGINARY DANGERS OF BALLOONING

ONE of the most astonishing adventures I had during this period of spherical ballooning took place directly over Paris.

I had started from Vaugirard with four invited guests in a large balloon constructed for me after I had tired of making solitary trips in the little "Brazil."

From the start there seemed to be very little wind. I rose slowly, seeking an air current. At 1000 metres ($\frac{3}{4}$ of a mile high) I found nothing. At 1500 metres (one mile) we still remained almost stationary. Throwing out more ballast we rose to 2000 metres ($1\frac{1}{4}$ mile), when a vagrant breeze started to take us over the centre of Paris.

When we had arrived at a point over the Louvre . . . it left us! We descended . . . and found nothing!

Then happened the ludicrous thing. In a blue sky without a cloud, bathed in sunlight, and with the faint yelps of all the dogs of Paris mounting to our ears, we lay becalmed! Up we went again, hunting an air current. Down we went again, hunting an air current. Up and down, up and down! Hour after hour passed, and we remained always hanging, always over Paris!

At first we laughed. Then we grew tired. Then almost alarmed. At one time I had even the idea of landing in Paris itself, near the Gare de Lyon, where I perceived an open space. Yet the attempt would have been dangerous, because my four companions could not be depended on for coolness in an emergency. They had not the ballooning habit.

Worst of all, we were now losing gas. Drifting slowly eastward hour after hour one by one the sacks of ballast had been emptied. By the time that we had reached the Vincennes wood we had begun to throw out miscellaneous objects—ballast-sacks, the luncheon-baskets, two light camp-stools, two kodaks, and a case of photographic plates!

All during this latter period we were quite

low — not over 800 yards above the tree-tops. Now, as we sank lower, we had a real fright. Would not the guide rope at least curl itself around some tree and hold us there for hours? So we struggled to maintain our altitude above the tree-tops, until all at once a queer little wind gust took us over the Vincennes race-course.

"Now is our time!" I exclaimed to my companions. "Hold fast!"

With this I pulled on the valve rope, and we came down with celerity but scarcely any shock.

Personally, I have felt not only fear but also pain and real despair in a spherical balloon. It has not been often, because no sport is more regularly safe and mild and pleasurable. Such real dangers as it has are confined usually to the landing, and the balloonist of experience knows how to meet them; while from its imaginary dangers in the air one is regularly very safe. Therefore the particular adventure, full of pain and fear, that I recall to mind was all the more remarkable in that it occurred in high altitude.

It happened at Nice in 1900, when I went up

from the Place Masséna in a good-sized spherical balloon, alone, and intending to drift a few hours only amid the enchanting scenery of the mountains and the sea.

The weather was fine, but the barometer soon fell, indicating storm. For a time the wind took me in the direction of Cimiez, but as I rose it threatened to carry me out to sea. I threw out ballast, abandoned the current, and mounted to the height of about a mile.

Shortly after this I let the balloon go down again, hoping to find a safe air current, but when within 300 yards of the ground, near the Var, I noticed that I had ceased descending. As I had determined to land soon in any case I pulled on the valve rope and let out more gas. And here the terrible experience began.

I could not go down. I glanced at the barometer, and found, indeed, that I was going up. Yet I ought to be descending, and I felt—by the wind and everything—that I must be descending. Had I not let out gas?

To my great uneasiness I discovered only too soon what was wrong. In spite of my continuous apparent descent I was, nevertheless, being lifted by an enormous column of air rushing

upward. While I fell in it I rose rapidly higher with it.

I opened the valve again; it was useless. The barometer showed that I had reached a still greater altitude, and I could now take account of the fact by the way in which the land was disappearing under me. I now closed the valve to save my gas. There was nothing but to wait and see what would happen.

The upward-rushing column of air continued to take me to a height of 3000 metres (almost 2 miles). I could do nothing but watch the barometer. Then, after what seemed a long time, it showed that I had begun descending.

When I began to see land I threw out ballast, not to strike the earth too quickly. Now I could perceive the storm beating the trees and shrubbery. Up in the storm itself I had felt nothing.

Now, too, as I continued falling lower, I could see how swiftly I was being carried laterally. By the time I perceived the coming danger I was in it. Carried along at a terrific rate, knocking against the tops of trees, and continually threatened with a painful death, I threw out my anchor. It caught in trees and shrubs and broke away. Had it been heavy timber all would have been over

with me. As it chanced, I was dragged through the small trees and yielding shrubbery, my face a mass of cuts and bruises, my clothes torn from my back, in pain and strain, fearing the worst, and able to do nothing to save myself. Just as I had given myself up for lost the guide rope wound itself around a tree and held. I was precipitated from the basket, and fell unconscious. When I came to I had to walk some distance until I met some peasants. They helped me back to Nice, where I went to bed, and had the doctors sew me up.

During the early period when I was glad to make public ascents for my balloon constructor I had undergone a somewhat similar experience, and that by night. The ascent took place at Péronne, in the north of France, one stormy afternoon, quite late. Indeed, I started in spite of thunder threatening in the distance, a gloomy semi-twilight all around me, and the remonstrances of the public, among whom it was known that I was not an aeronaut by trade. They feared my inexperience, and wished me either to renounce the ascent or else to oblige me to take up the balloon constructor with me, he being the responsible organiser of the *fête*.

I would listen to nothing, and started off as I had planned. Soon I had cause to regret my rashness. I was alone, lost in the clouds, amid flashes of lightning and claps of thunder, in the rapidly-approaching darkness of the night!

On, on I went tearing in the blackness. I knew that I must be going with great speed, yet felt no motion. I heard and felt the storm. I formed a part of the storm. I felt myself in great danger, yet the danger was not tangible. With it there was a fierce kind of joy. What shall I say? How shall I describe it? Up there in the black solitude, amid the lightning flashes and the thunderclaps, I was a part of the storm.

When I landed the next morning—long after I had sought a higher altitude and let the storm pass on beneath me—I found that I was well into Belgium. The dawn was peaceful, so that my landing took place without difficulty. I mention this adventure because it was made account of in the papers of the time, and to show that night ballooning, even in a storm, may be more dangerous in appearance than reality. Indeed, night ballooning has a charm that is all its own.

One is alone in the black void—true, in a murky

limbo, where one seems to float without weight, without a surrounding world—a soul freed from the weight of matter. Yet now and again there are the lights of earth to cheer one. We see a point of light far on ahead. Slowly it expands. Then where there was one blaze there are countless bright spots. They run in lines, with here and there a brighter cluster. We know that it is a city.

Then, again, it is out into the lone land, with only a faint glow here and there. When the moon rises we see, perhaps, a faint curling line of grey. It is a river, with the moonlight falling on its waters.

There is a flash upward and a faint roar. It is a railway train, the locomotive's fires, maybe, illuminating for a moment its smoke as it rises.

Then for safety we throw out more ballast, and rise through the black solitudes of the clouds into a soul-lifting burst of splendid starlight. There, alone with the constellations, we await the dawn.

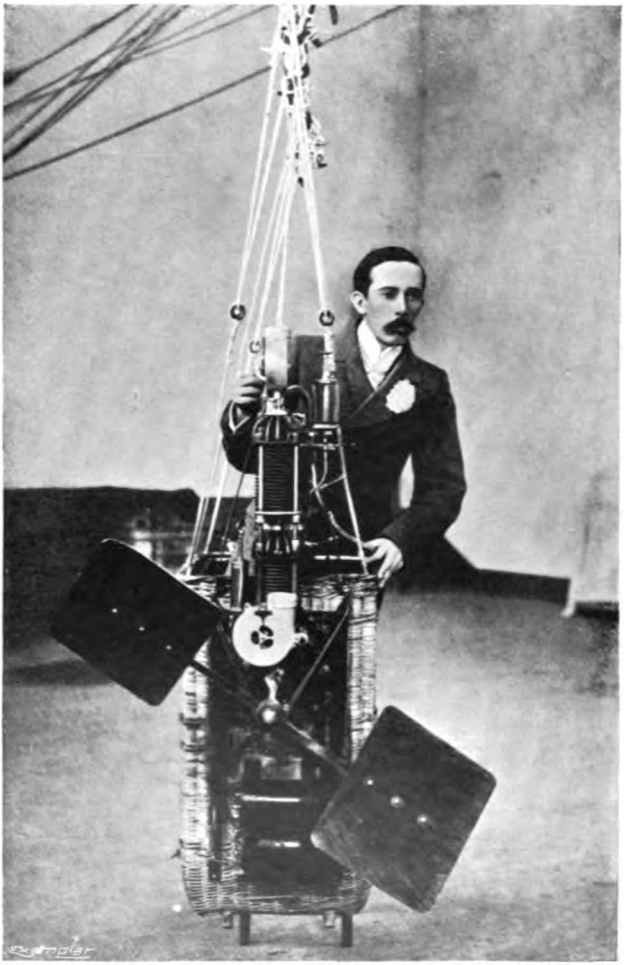
And when the dawn comes, red and gold and purple in its glory, one is almost loth to seek the earth again, although the novelty of landing in who knows what part of Europe affords still another unique pleasure.

DANGERS OF BALLOONING

For many the great charm of all ballooning lies here. The balloonist becomes an explorer. Say that you are a young man who would roam, who would enjoy adventures, who would penetrate the unknown and deal with the unexpected—but say that you are tied down at home by family and business. I advise you to take to spherical ballooning. At noon you lunch peaceably amid your family. At 2 P.M. you mount. Ten minutes later you are no longer a commonplace citizen—you are an explorer, an adventurer of the unknown as truly as they who freeze on Greenland's icy mountains or melt on India's coral strand.

You know but vaguely where you are and cannot know where you are going. Yet much may depend upon your choice as well as your skill and experience. The choice of altitude is yours—whether to accept this current or mount higher and go with another. You may mount above the clouds, where one breathes oxygen from tubes, while the earth, in the last glimpse you had of it, seems to spin beneath you, and you lose all bearings; or you may descend and scud along the surface, aided by your guide rope and a dipperful of ballast to leap over trees and houses—giant leaps made without effort.

Then when the time comes to land there is the true explorer's zest of coming on unknown peoples like a god from a machine. "What country is this?" Will the answer come in German, Russian, or Norwegian? Paris Aéro Club members have been shot at when crossing European frontiers. Others, landing, have been taken prisoners to the burgomeister or the military governor, to languish as spies while the telegraph clicked to the far-off capital, and then to end the evening over champagne at an officers' enthusiastic mess. Still others have had to strive with the dangerous ignorance and superstition even of some remote little peasant population. These are the chances of the winds.



MOTOR OF "No. 1"

CHAPTER VI

I YIELD TO THE STEERABLE BALLOON IDEA

DURING my ascent with M. Machuron, while our guide rope was wrapped around the tree and the wind was shaking us so outrageously, he improved the occasion to discourage me against all steerable ballooning.

"Observe the treachery and vindictiveness of the wind," he cried between shocks. "We are tied to the tree, yet see with what force it tries to jerk us loose." (Here I was thrown again to the bottom of the basket.) "What screw propeller could hold a course against it? What elongated balloon would not double up and take you flying to destruction?"

It was discouraging. Returning to Paris by rail I gave up the ambition to continue Giffard's trials, and this state of mind lasted with me for weeks. I would have argued fluently against the dirigibility of balloons. Then came a new period of temptation, for a long-cherished idea

dies hard. When I took account of its practical difficulties I found my mind working automatically to convince itself that they were not. I caught myself saying: "If I make a cylindrical balloon long enough and thin enough it will cut the air . . . " and, with respect to the wind, "shall I not be as a sailing yachtsman who is not criticised for refusing to go out in a squall?"

At last an accident decided me. I have always been charmed by simplicity, while complications, be they never so ingenious, repel me. Automobile tricycle motors happened to be very much perfected at the moment. I delighted in their simplicity, and, illogically enough, their merits had the effect of deciding my mind against all other objections to steerable ballooning.

"I will use this light and powerful motor," I said. "Giffard had no such opportunity."

Giffard's primitive steam-engine, weak in proportion to its weight, spitting red-hot sparks from its coal fuel, had afforded that courageous innovator no fair chance, I argued. I did not dally a single moment with the idea of an electric motor, which promises little danger, it is true, but which has the capital ballooning defect of being the

heaviest known engine, counting the weight of its battery. Indeed, I have so little patience with the idea that I shall say no more about it except to repeat what Mr Edison said to me on this head in April 1902: "You have done well," he said, "to choose the petroleum motor. It is the only one of which an aeronaut can dream in the present state of the industry; and steerable balloons with electric motors, especially as they were fifteen or twenty years ago, could have led to no result. That is why the Tissandier brothers gave them up."

In spite of the recent immense improvements made in the steam-engine it would not have been able to decide me in favour of steerable ballooning. Motor for motor it is, perhaps, better than the petroleum motor, but when you compare the boiler with the carburator the latter weighs grammes per horse-power while the boiler weighs kilogrammes. In certain light steam-motors, that are lighter even than petroleum motors, the boiler always ruins the proportion. With one pound of petroleum you can exert one horse-power during one hour. To get this same energy from the most improved steam-engine you will want many kilogrammes of water and of fuel, be it

petroleum or other. Even condensing the water, you cannot have less than several kilogrammes per horse-power.

Then if one uses coal fuel with the steam-motor there are the burning sparks; while if one uses petroleum with burners you have a great amount of fire. We must do the petroleum motor the justice to admit that it makes neither flame nor burning sparks.

At the present moment I have a Clement petroleum motor that weighs but 2 kilogrammes (4½ lbs.) per horse-power. This is my 60 horse-power "No. 7," whose total weight is but 120 kilogrammes (264 lbs.). Compare this with the new steel-and-nickel battery of Mr Edison, which promises to weigh 18 kilogrammes (40 lbs.) per horse-power.

The light weight and the simplicity of the little tricycle motor of 1897 are, therefore, responsible for all my trials. I started from this principle: To make any kind of success it would be necessary to economise weight, and so comply with the pecuniary, as well as the mechanical, conditions of the problem.

Nowadays I build air-ships in a large way. I am in it as a kind of lifework. Then I was but

a half-decided beginner, unwilling to spend large sums of money in a doubtful project.

Therefore I resolved to build an elongated balloon just large enough to raise, along with my own 50 kilogrammes (110 lbs.) of weight, as much more as might be necessary for the basket and rigging, motor, fuel, and absolutely indispensable ballast. In reality I was building an airship to fit my little tricycle motor.

I looked for the workshop of some small mechanic near my residence in the centre of residential Paris where I could have my plans executed under my own eyes and could apply my own hands to the task. I found such an one in the Rue du Colisée. There I first worked out a tandem of two cylinders of a tricycle motor—that is, their prolongation, one after the other, to work the same connecting-rod while fed by a single carburator.

To bring everything down to a minimum weight, I cut out from every part of the motor whatever was not strictly necessary to solidity. In this way I realised something that was interesting in those days—a 8½ horse-power motor that weighed 30 kilogrammes (66 lbs.).

I soon had an opportunity to test my tandem

motor. The great series of automobile road-races, which seems to have had its climax in Paris-Madrid in 1903, was raising the power of these wonderful engines by leaps and bounds year after year. Paris-Bordeaux in 1895 was won with a 4 horse-power machine at an average speed of 25 kilometres (15½ miles) per hour. In 1896 Paris-Marseilles-and-return was accomplished at the rate of 30 kilometres (18½ miles) per hour. Now, in 1897, it was Paris-Amsterdam. Although not entered for the race it occurred to me to try my tandem motor attached to its original tricycle. I started, and to my contentment found that I could keep well up with the pace. Indeed, I might have won a good place in the finish—my vehicle was the most powerful of the lot in proportion to its weight, and the average speed of the winner was only 40 kilometres (25 miles) per hour—had I not begun to fear that the jarring of my motor in so strenuous an effort might in the long run derange it, and I imagined I had more important work for it to do.

For that matter, my automobiling experience has stood me in good stead with my air-ships. The petroleum motor is still a delicate and capricious thing, and there are sounds in its

spitting rumble that are intelligible only to the long-experienced ear. Should the time come in some future flight of mine when the motor of my air-ship threatens danger I am convinced that my ear will hear, and I shall heed, the warning. This almost instinctive faculty I owe only to experience. Having broken up the tricycle for the sake of its motor I purchased at about this time an up-to-date 6 horse-power Panhard, with which I went from Paris to Nice in 54 hours—night and day, without stop—and had I not taken up dirigible ballooning I must have become a road-racing automobile enthusiast, continually exchanging one type for another, continually in search of greater speed, keeping pace with the progress of the industry, as so many others do, to the glory of French mechanics and the new Parisian sporting spirit.

But my air-ships stopped me. While experimenting I was tied down to Paris. I could take no long trips, and the petroleum automobile, with its wonderful facility for finding fuel in every hamlet, lost its greatest use in my eyes. In 1898 I happened to see what was to me an unknown make of light American electric buggy. It appealed alike to my eye, my needs, and my reason,

and I bought it. I have never had cause to regret the purchase. It serves me for running about Paris, and it goes lightly, noiselessly, and without odour.

I had already handed the plan of my balloon envelope to the constructors. It was that of a cylindrical balloon terminating fore and aft in cones, 25 metres (82½ feet) long, with a diameter of 8·5 metres (11½ feet) and a gas capacity of 180 cubic metres (6354 cubic feet). My calculations had left me only 30 kilogrammes (66 lbs.) for both the balloon material and its varnish. Therefore I gave up the usual network and *chemise*, or outer cover; indeed, I considered this second envelope, holding the balloon proper within it, to be not only superfluous but harmful, if not dangerous. Instead I attached the suspension cords of my basket directly to the balloon envelope by means of small wooden rods introduced into long horizontal hems sewed on both sides to its stuff for a great part of the balloon's length. Again, in order not to pass my 30 kilogrammes (66 lbs.), including varnish, I was obliged to have recourse to my Japanese silk, which had proved so staunch in the "Brazil."

After glancing at this order for the balloon

envelope M. Lachambre at first refused it plumply. He would not make himself a party to such rashness. But when I recalled to his memory how he had said the same thing with respect to the "Brazil," and went on to assure him that, if necessary, I would cut and sew the balloon with my own hands, he gave way to me and undertook the job. He would cut and sew and varnish the balloon according to my plans.

The balloon envelope being thus put under way I prepared my basket, motor, propeller, rudder, and machinery. When they were completed I made many trials with them, suspending the whole system by a cord from the rafters of the workshop, starting the motor, and measuring the force of the forward swing caused by the propeller working on the atmosphere behind it. Holding back this forward movement by means of a horizontal rope attached to a dynamometer, I found that the traction power developed by the motor in my propeller with two arms, each measuring one metre across, was as high as 11·4 kilogrammes (25 lbs.). This was a figure that promised good speed to a cylindrical balloon of my dimensions, whose length was equal to nearly seven times its diameter. With 1200

turns to the minute the propeller, which was attached directly to the motor shaft, might easily, if all went well, give the air-ship a speed of not less than 8 metres (26¼ feet) per second.

The rudder I made of silk, stretched over a triangular steel frame. There now remained nothing to devise but a system of shifting weights, which from the very first I saw would be indispensable. For this purpose I placed two bags

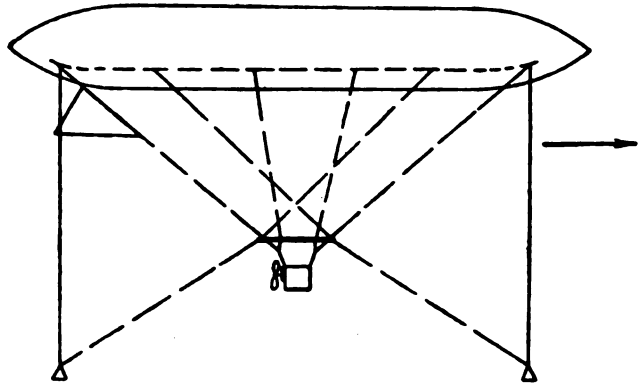


Fig. 3.

of ballast, one fore and one aft, suspended from the balloon envelope by cords. By means of lighter cords each of these two weights could be drawn into the basket (see Fig. 3), thus shifting the centre of gravity of the whole system. Pulling in the fore weight would cause the stem

of the balloon to point diagonally upward; pulling in the aft weight would have just the opposite effect. Besides these I had a guide rope some 60 metres (200 feet) long, which could also be used, at need, as shifting ballast.

All this occupied several months, and the work was all carried on in the little machine-shop of the Rue du Colisée, only a few steps from the place where later the Paris Aéro Club was to have its first offices.

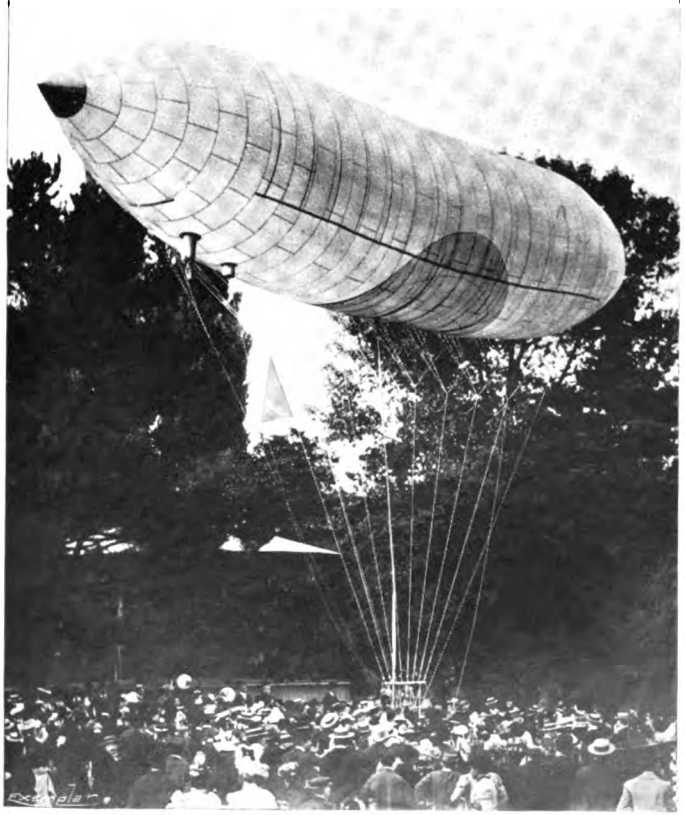
CHAPTER VII

MY FIRST AIR-SHIP CRUISES (1898)

In the middle of September 1898 I was ready to begin in the open air. The rumour had spread among the aeronauts of Paris, who formed the nucleus of the Aéro Club, that I was going to carry up a petroleum motor in my basket. They were sincerely disquieted by what they called my temerity, and some of them made friendly efforts to show me the permanent danger of such a motor under a balloon filled with a highly inflammable gas. They begged me instead to use the electric motor—"which is infinitely less dangerous."

I had arranged to inflate the balloon at the Jardin d'Acclimatation, where a captive balloon was already installed and furnished with everything needful daily. This gave me facilities for obtaining, at one franc per cubic metre, the 180 cubic metres (6354 cubic feet) of hydrogen which I needed.

On September 18th my first air-ship — the



THE "SANTOS-DUMONT No. 1"
FIRST START

"Santos-Dumont No. 1," as it has since been called to distinguish it from those which followed —lay stretched out on the turf amid the trees of the beautiful Jardin d'Acclimatation, the new Zoological Garden of the west of Paris. To understand what happened I must explain the starting of spherical balloons from such places where groups of trees and other obstructions surround the open space.

When the weighing and balancing of the balloon are finished and the aeronauts have taken their place in the basket the balloon is ready to quit the ground with a certain ascensional force. Thereupon aids carry it toward an extremity of the open space in the direction from which the wind happens to be blowing, and it is there that the order: "Let go all!" is given. In this way the balloon has the entire open space to cross before reaching the trees or other obstructions which may be opposite and toward which the wind would naturally carry it. So it has space and time to rise high enough to pass over them. Moreover, the ascensional force of the balloon is regulated accordingly: it is very little if the wind be light; it is more if the wind be stronger.

I had thought that my air-ship would be able to

go against the wind that was then blowing, therefore I had intended to place it for the start at precisely the other end of the open space from that which I have described—that is, down stream, and not up stream in the air current with relation to the open space surrounded by trees. I would thus move out of the open space without difficulty, having the wind against me—for under such conditions the relative speed of the air-ship ought to be the difference between its absolute speed and the velocity of the wind—and so by going against the air current I should have plenty of time to rise and pass over the trees. Evidently it would be a mistake to place the air-ship at a point suitable for an ordinary balloon without motor and propeller.

And yet it was there that I did place it, not by my own will, but by the will of the professional aeronauts who came in the crowd to be present at my experiment. In vain I explained that by placing myself "up stream" in the wind with relation to the centre of the open space I should inevitably risk precipitating the air-ship against the trees before I would have time to rise above them, the speed of my propeller being superior to that of the wind then blowing.

All was useless. The aeronauts had never seen a dirigible balloon start off. They could not admit of its starting under other conditions than those of a spherical balloon, in spite of the essential difference between the two. As I was alone against them all I had the weakness to yield.

I started off from the spot they indicated, and within a second's time I tore my air-ship against the trees, as I had feared I should do. After this deny if you can the existence of a fulcrum in the air.

This accident at least served to show the effectiveness of my motor and propeller in the air to those who doubted it before.

I did not waste time in regrets. Two days later, on September 20th, I actually started from the same open space, this time choosing my own starting-point.

I passed over the tops of the trees without mishap, and at once began sailing around them, to give on the spot a first demonstration of the air-ship to the great crowd of Parisians that had assembled. I had their sympathy and applause then, as I have ever had it since; the Parisian public has always been a kind and enthusiastic witness of my efforts.

Under the combined action of the propeller impulse, of the steering rudder, of the displacement of the guide rope, and of the two sacks of ballast sliding backward and forward as I willed, I had the satisfaction of making my evolutions in every direction—to right and left, and up and down.

Such a result encouraged me, and, being inexperienced, I made the great mistake of mounting high in the air to 400 metres (1300 feet), an altitude that is considered nothing for a spherical balloon, but which is absurd and uselessly dangerous for an air-ship under trial.

At this height I commanded a view of all the monuments of Paris. I continued my evolutions in the direction of the Longchamps racecourse, which from that day I chose for the scene of my aerial experiments.

So long as I continued to ascend the hydrogen increased in volume as a consequence of the atmospheric depression. So by its tension the balloon was kept taut, and everything went well. It was not the same when I began descending. The air pump, which was intended to compensate the contraction of the hydrogen, was of insufficient capacity. The balloon, a long cylinder, all at once began to fold in the middle like a pocket

knife, the tension of the cords became unequal, and the balloon envelope was on the point of being torn by them. At that moment I thought that all was over, the more so as the descent, which had begun, could no longer be checked by any of the usual means on board, where nothing worked.

The descent became a fall. Luckily, I was falling in the neighbourhood of the grassy turf of Bagatelle, where some big boys were flying kites. A sudden idea struck me. I cried to them to grasp the end of my guide rope, which had already touched the ground, and to run as fast as they could with it *against the wind.*

They were bright young fellows, and they grasped the idea and the rope at the same lucky instant. The effect of this help *in extremis* was immediate, and such as I had hoped. By the manœuvre we lessened the velocity of the fall, and so avoided what would have otherwise have been a bad shaking-up, to say the least.

I was saved for the first time. Thanking the brave boys, who continued aiding me to pack everything into the air-ship's basket, I finally secured a cab and took the relics back to Paris.

CHAPTER VIII

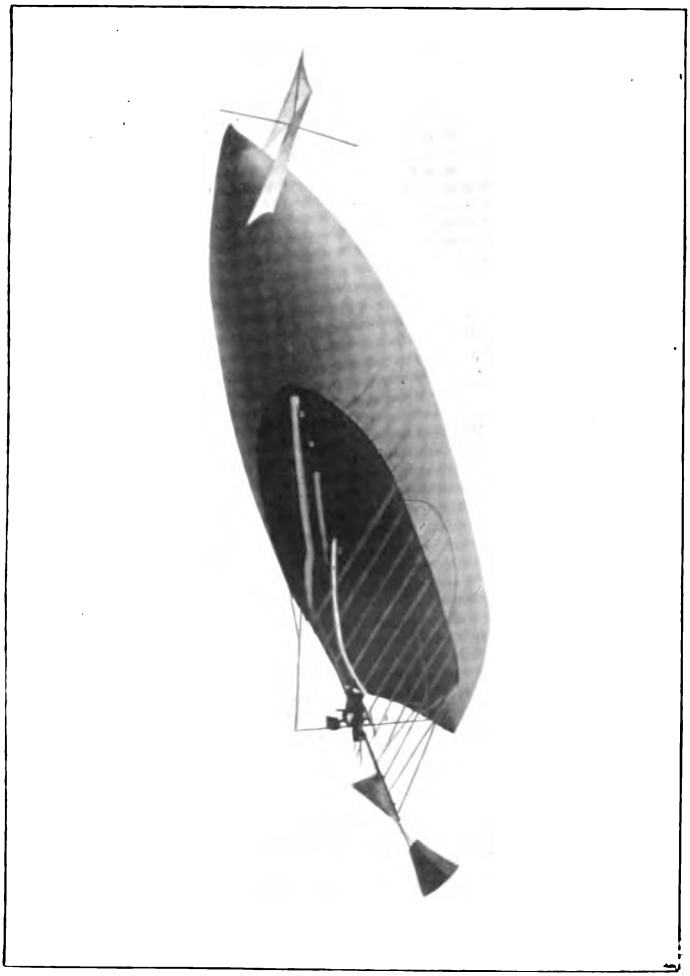
HOW IT FEELS TO NAVIGATE THE AIR

NOTWITHSTANDING the breakdown I felt nothing but elation that night. The sentiment of success filled me: I had navigated the air.

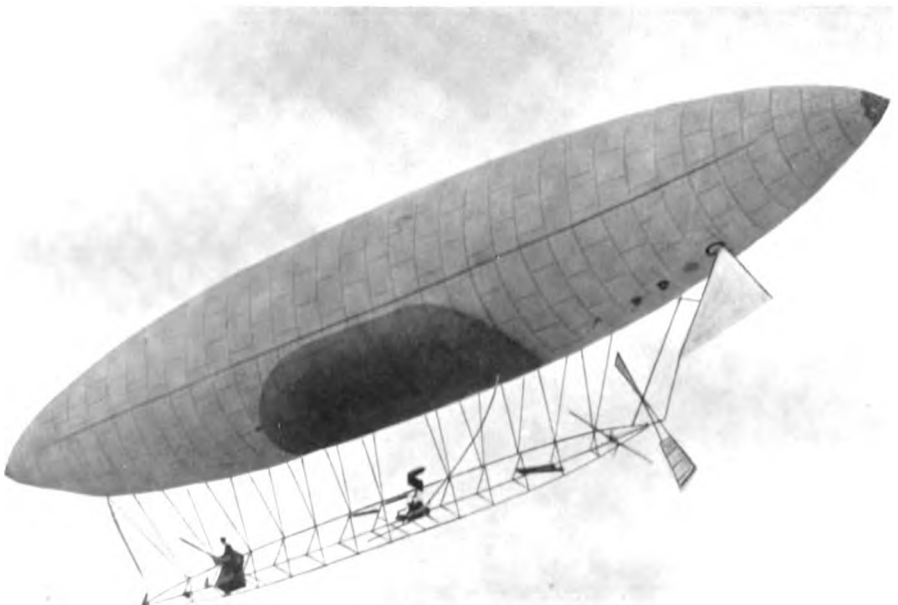
I had performed every evolution prescribed by the problem. *The breakdown itself had not been due to any cause foreseen by the professional aeronauts.*

I had mounted without sacrificing ballast. I had descended without sacrificing gas. My shifting weights had proved successful, and it would have been impossible not to recognise the capital triumph of these oblique flights through the air. No one had ever made them before.

Of course, when starting, or shortly after leaving the ground, one has sometimes to throw out ballast to balance the machine, as one may have made a mistake and started with the air-ship far too heavy. What I have referred to are manœuvres in the air.



"No. 4" FREE DIAGONAL MOVEMENT UP



"No. 6." FREE DIAGONAL MOVEMENT DOWN

My first impression of aerial navigation was, I confess, surprise to feel the air-ship going straight ahead. It was astonishing to feel the wind in my face. In spherical ballooning we go with the wind, and do not feel it. True, in rising and descending the spherical balloonist feels the friction of the atmosphere, and the vertical oscillation makes the flag flutter, but in the horizontal movement the ordinary balloon seems to stand still, while the earth flies past under it.

As my air-ship ploughed ahead the wind struck my face and fluttered my coat, as on the deck of a transatlantic liner, though in other respects it will be more accurate to liken aerial to river navigation with a steamboat. It is not like sail navigation, and all talk about "tacking" is meaningless. If there is any wind at all it is in a given direction, so that the analogy with a river current is complete. When there is no wind at all we may liken it to the navigation of a smooth lake or pond. It will be well to understand this matter.

Suppose that my motor and propeller push me through the air at the rate of 20 miles an hour, I am in the position of a steamboat captain whose propeller is driving him up or down the river at

the rate of 20 miles an hour. Imagine the current to be 10 miles per hour. If he navigates against the current he accomplishes 10 miles an hour with respect to the shore, though he has been travelling at the rate of 20 miles an hour through the water. If he goes with the current he accomplishes 30 miles an hour with respect to the shore, though he has not been going any faster through the water. This is one of the reasons why it is so difficult to estimate the speed of an air-ship.

It is also the reason why air-ship captains will always prefer to navigate for their own pleasure in calm weather, and, when they find an air current against them, will steer obliquely upward or downward to get out of it. Birds do the same thing. The sailing yachtsman whistles for a fair breeze, without which he can do nothing, but the river steamboat captain will always hug the shore to avoid the freshet, and will time his descent of the river by the outgoing, rather than the incoming, tide. We air-shipmen are steamboat captains and not sailing yachtsmen.

The navigator of the air, however, has the one great advantage—he can leave one current for another. The air is full of varying currents. Mounting, he will find an advantageous breeze

or else a calm. These are strictly practical considerations, having nothing to do with the air-ship's ability to battle with the breeze when obliged to do it.

Before going on my first trip I had wondered if I should be sea-sick. I foresaw that the sensation of mounting and descending obliquely with my shifting weights might be unpleasant. And I looked forward to a good deal of pitching (*tangage*), as they say on board ship—of rolling there would not be so much — but both sensations would be novel in ballooning, for the spherical balloon gives no sensation of movement at all.

In my first air-ship, however, the suspension was very long, approximating that of a spherical balloon. For this reason there was very little pitching. And, speaking generally, since that time, though I have been told that on this or that trip my air-ship pitched considerably, I have never been sea-sick. It may be due in part to the fact that I am rarely subject to this ill upon the water. Back and forth between Brazil and France and between France and the United States I have had experience of all kinds of weather. Once, on the way to Brazil,

the storm was so violent that the grand piano went loose and broke a lady's leg, yet I was not sea-sick.

I know that what one feels most distressingly at sea is not so much the movement as that momentary hesitation just before the boat pitches, followed by the malicious dipping or mounting, which never comes quite the same, and the shock at top and bottom. All this is powerfully aided by the smells of the paint, varnish, tar, mingled with the odours of the kitchen, the heat of the boilers, and the stench of the smoke and the hold.

In the air-ship there is no smell — all is pure and clean — and the pitching itself has none of the shocks and hesitations of the boat at sea. The movement is suave and flowing, which is doubtless owing to the lesser resistance of the air waves. The pitches are less frequent and rapid than those at sea; the dip is not brusquely arrested, so that the mind can anticipate the curve to its end; and there is no shock to give that queer, "empty" sensation to the solar plexus.

Furthermore, the shocks of a transatlantic liner are due first to the fore, and then to the after, part of the giant construction rising out of the

water to plunge into it again. The air-ship never leaves its medium—the air—in which it only swings.

This consideration brings me to the most remarkable of all the sensations of aerial navigation. On my first trip it actually shocked me! This is the utterly new sensation of movement in an extra dimension!

Man has never known anything like free vertical existence. Held to the plane of the earth, his movement "down" has scarcely been more than to return to it after a short excursion "up," our minds remaining always on the plane surface even while our bodies may be mounting; and this is so much the case that the spherical balloonist as he rises has no sense of movement, but gains the impression that the earth is descending below him.

With respect to combinations of vertical and horizontal movements, man is absolutely without experience of them. Therefore, as all our sensations of movement are practically in two dimensions, this is the extraordinary novelty of aerial navigation that it affords us experiences — not in the fourth dimension, it is true—but in what is practically an extra dimension—the third—so

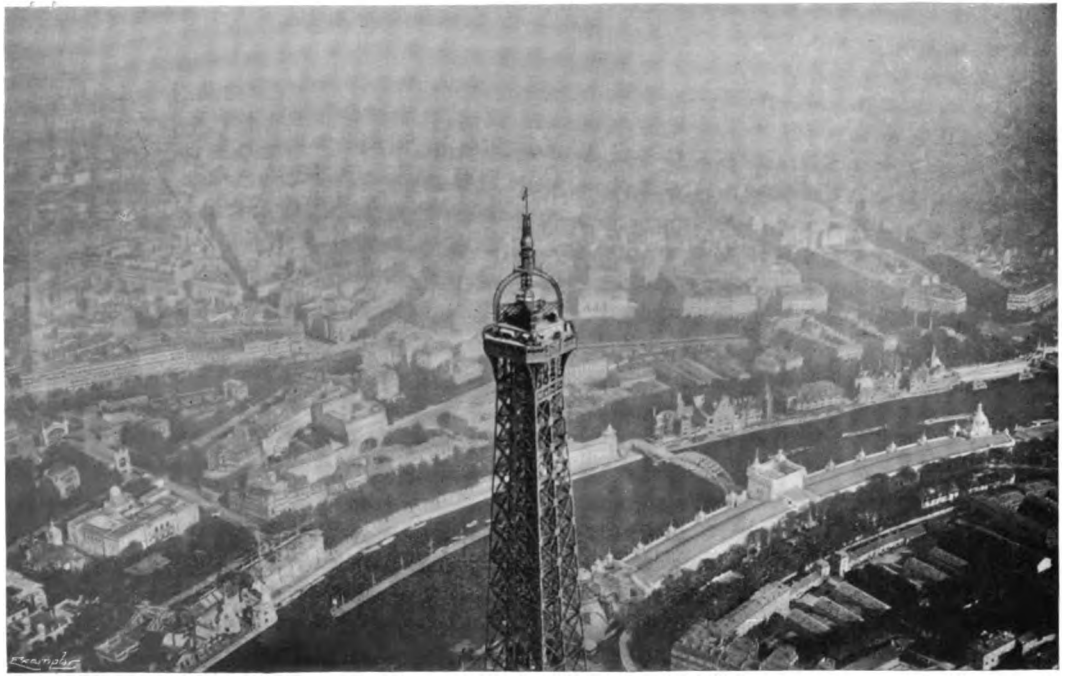
that the miracle is similar. Indeed, I cannot describe the delight, the wonder, and intoxication of this free diagonal movement onward and upward or onward and downward, combined at will with brusque changes of direction horizontally when the air-ship answers to a touch of the rudder! The birds have this sensation when they spread their great wings and go tobogganning in curves and spirals through the sky!

Por mares nunca d'antes navegados!
(O'er seas hereto unsailed.)

The line of our great poet echoed in my memory from childhood. After this first of all my cruises I had it put on my flag.

It is true that spherical ballooning had prepared me for the mere sensation of height; but that is a very different matter. It is, therefore, curious that, prepared on this head as I was, the mere thought of height should have given me my only unpleasant experience. What I mean is this:

The wonderful new combinations of vertical and horizontal movements, utterly out of previous human experience, caused me neither surprise nor trouble. I would find myself ploughing diagonally upward through the air with a kind of instinctive



THE HOUSETOPS LOOK SO DANGEROUS

liberty. And yet when moving horizontally—as you would say, in the natural position—a glance downwards at the house-tops disquieted me.

"What if I should fall?" the thought came. The house-tops looked so dangerous with their chimney-pots for spikes. One seldom has this thought in a spherical balloon, because we know that the danger in the air is *nil*: the great spherical balloon can neither suddenly lose its gas nor burst. My little air-ship balloon had to support not only exterior but interior pressure as well—which is not the case with a spherical balloon, as I shall explain in the next chapter—and any injury to the cylindrical form of my air-ship balloon by loss of gas might prove fatal.

While over the house-tops I felt that it would be bad to fall, but as soon as I left Paris and was navigating over the forest of the Bois de Boulogne the idea left me entirely. Below there seemed to be an ocean of greenery, soft and safe.

It was while over the continuation of this greenery in the grassy *pelouse* of the Longchamps racecourse that my balloon, having lost a great deal of its gas, began to double on itself. Previously I had heard a noise. Looking up, I saw

that the long cylinder of the balloon was beginning to break. Then I was astonished and troubled. I wondered what I could do.

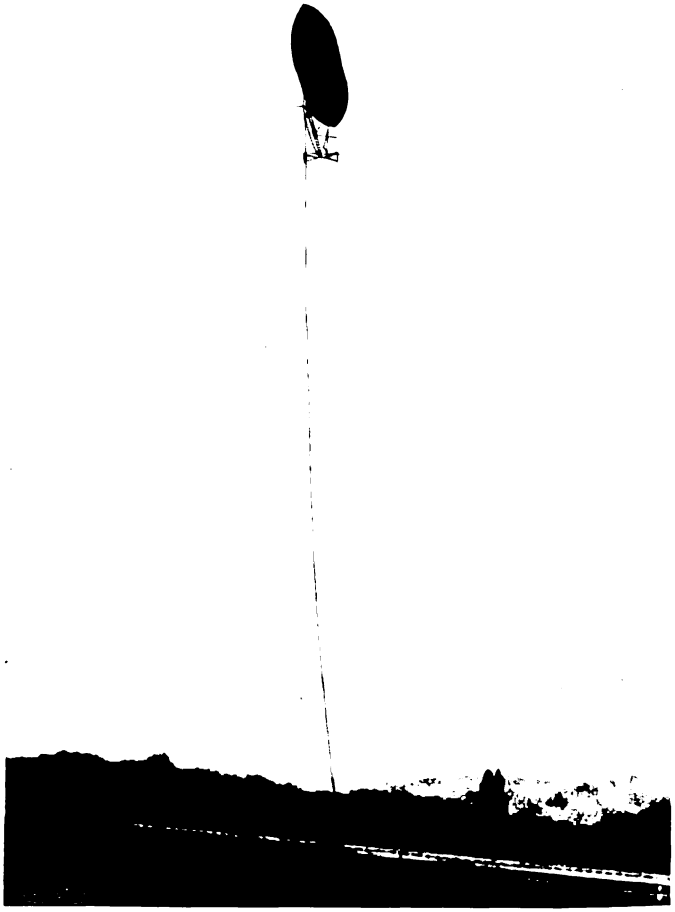
I could not think of anything to do. I might throw out ballast. That would cause the air-ship to rise, and the decreased pressure of the atmosphere would doubtless permit the expanding gas to straighten out the balloon again taut and strong. But I remembered that I must always come down again when all the danger would repeat itself, and worse even than before, from the more gas I should have lost. There was nothing to do but to go on down instantly.

I remember having the sure idea: "If that balloon cylinder doubles any more, the ropes by which I am suspended to it will work at different strengths and will begin to break one by one as I go down!"

For the moment I was sure that I was in the presence of death. Well, I will tell it frankly, my sentiment was almost entirely that of waiting and expectation.

"What is coming next?" I thought. "What am I going to see and know in a few minutes? Whom shall I see after I am dead?"

The thought that I should be meeting my father



OVER THE BOIS DE BOULOGNE. BELOW THERE SEEMED TO BE AN OCEAN OF GREENERY, SOFT AND SAFE

in a few minutes thrilled me. Indeed, I think that in such moments there is no room either for regret or terror. The mind is too full of looking forward. One is frightened only so long as one still has a chance.

CHAPTER IX

EXPLOSIVE ENGINES AND INFLAMMABLE GASES

I HAVE been so often and so sincerely warned against what is taken for granted to be the patent danger of operating explosive engines under masses of inflammable gases that I may be pardoned for stopping a moment to disclaim undue or thoughtless rashness.

Very naturally, from the first, the question of physical danger to myself called for consideration. I was the interested party, and I tried to view the question from all points. Well, the outcome of these meditations was to make me fear fire very little, while doubting other possibilities against which no one ever dreamed of warning me.

I remember that while working on the first of all my air-ships in that little carpenter shop of the Rue du Colisée I used to wonder how the vibrations of the petroleum motor would affect the system when it got in the air.

In those days we did not have the noiseless

automobiles, free from great vibration, of the present. Nowadays, even the colossal 80 and 90 horse-power motors of the latest racing types can be started and stopped as gently as those great steel hammers in iron foundries, whose engineers make a trick of cracking the top of an egg with them without breaking the rest of the shell.

My tandem motor of two cylinders, working the same connecting-rod and fed by a single carburator, realised 8½ horse-power—at that time a considerable force for its weight—and I had no idea how it would act off terra firma. I had seen motors "jump" along the highway. What would mine do in its little basket, that weighed almost nothing, and suspended from a balloon that weighed less than nothing?

You know the principle of these motors? One may say that there is gasoline in a receptacle. Air passing through it comes out mixed with gasoline gas, ready to explode. You give a whirl to a crank, and the thing begins working automatically. The piston goes down, sucking combined gas and air into the cylinder. Then the piston comes back and compresses it. At that moment an electric spark is struck. An explosion follows instantly; and the piston goes down, pro-

ducing work. Then it goes up, throwing out the product of combustion. Thus with the two cylinders there was one explosion for every turn of the shaft.

Wishing to have my mind clear on the question I took my tricycle, just as it was after I had left the Paris-Amsterdam race, and, accompanied by a capable companion, I steered it to a lonely part of the Bois de Boulogne. There in the forest I chose a great tree with low-hanging limbs. From two of them we suspended the motor tricycle by three ropes.

When we had well established the suspension my companion aided me to climb up and seat myself on the tricycle saddle. I was as in a swing. In a moment I would start the motor and learn something of my future success or failure.

Would the vibration of the explosive engine shake me back and forth, strain at the ropes until it had unequalised their tension, and then break them one by one? Would it jar the interior air balloon's pump and derange the big balloon's valves? Would it continually jerk and pull at the silk hems and the thin rods which were to hold my basket to the balloon? Free from the steadying influence of the solid ground,

would the jumping motor jar itself until it broke? And, breaking, might it not explode?

All this and more had been predicted by the professional aeronauts, and I had as yet no proof outside of reasoning that they might not be right on this or that topic.

I started the motor. I felt no particular vibration, and I was certainly not being shaken. I increased the speed, and felt *less* vibration! There could be no doubt about it—there was less vibration in this light-weight tricycle hanging in the air than I had regularly felt while travelling on the ground. It was my first triumph in the air!

I will say frankly that as I rose in the air on my first trip I had no fear of fire. What I feared was that the balloon might burst by reason of its interior pressure. I still fear it.

Before going up I had minutely tried the valves. I still try them minutely before each of my trips. The danger, of course, was that the valves might not work adequately, in which case the expanding of the gas as the balloon rose would cause the dreaded explosion. Here is the great difference between spherical and dirigible balloons. The spherical balloon is always open. When it is taut with gas it is shaped like an

apple; when it has lost part of its gas it takes the shape of a pear; but in each case there is a great hole in the bottom of the spherical balloon where the stem of the apple or the pear would be, and it is through this hole that the gas has opportunity to ease itself in the constant alternations of condensation and dilatation. Having such a free vent, the spherical balloon runs no risk of bursting in the air; but the price paid for this immunity is great loss of gas and, consequently, a fatal shortening of the spherical balloon's stay in the air. Some day a spherical balloonist will close up that hole; indeed, they already talk of doing it.

I was obliged to do it in my air-ship balloon, whose cylindrical form must be preserved at all cost. For me there must be no transformations as from apple to pear. Interior pressure only could guarantee me this. The valves to which I refer have since my first experiments been of all kinds—some very ingeniously interacting, others of extreme simplicity. But their object in each case has always been the same: to hold the gas tight in the balloon up to a certain pressure and then let only enough out to relieve dangerous interior pressure. It is easy to realise, therefore, that

should these valves refuse to act adequately the danger of bursting would be there.

This possible danger I acknowledged to myself, but it had nothing to do with fire from the explosive motor. Yet during all my preparations, and up to the moment of calling: "Let go all!" the professional aeronauts, completely overlooking this weak point of the air-ship, continued to warn me against fire, of which I had no fear at all!

"Do we dare strike matches in the basket of a spherical balloon?" they asked.

"Do we even permit ourselves the solace of a cigarette on trips that last for many hours?"

To me the cases did not seem the same. In the first place, why should one not light a match in the basket of a spherical balloon? If it be only because the mind vaguely connects the ideas of gas and flame the danger remains as ideal. If it be because of a real possibility of igniting gas that has escaped from the free hole in the stem of the spherical balloon it would not apply to me. My balloon, hermetically closed, except when excessive pressure should let either air or a very little gas escape through one of the automatic valves, might for a moment leave a little trail of gas *behind* it as it moved on horizontally or

diagonally, but there would be none in front where the motor was. (See Fig. 4.)

In this first air-ship I had placed the gas escape valves even farther from the motor than I place them to-day. The suspension cords being very

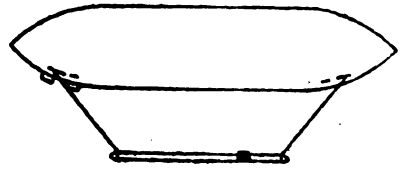


Fig. 4

long I hung in my basket far below the balloon. Therefore I asked myself:

"How could this motor, so far below the balloon, and so far in front of its escape valves, set fire to the gas enclosed in it when such gas is not inflammable until mixed with air?"

On this first trial, as in most since, I used hydrogen gas. Undoubtedly when mixed with air it is tremendously inflammable—but it must first mix with air. All my little balloon models are kept filled with hydrogen, and, so filled, I have more than once amused myself by burning *inside them*, not their hydrogen, but its mixture with the oxygen of the atmosphere. All one has to do is to insert in the balloon model a little

tube to furnish a jet of the room's atmosphere from an air pump and light it with the electric spark. Similarly, should a pin-prick have made ever so slight a vent in my air-ship balloon, the interior pressure would have sent out into the atmosphere a long thin stream of hydrogen that *might* have ignited had there been any flame near enough to do it. But there was none.

This was the problem. My motor did undoubtedly send out flames for, say, half-a-yard round about it. They were, however, mere flames, not still-burning products of incomplete combustion like the sparks of a coal-burning steam-engine. This admitted, how was the fact that I had a mass of hydrogen unmixed with air and well secured in a tight envelope so high above the motor to prove dangerous?

Turning the matter over and over in my mind I could see but one dangerous possibility from fire. This was the possibility of the petroleum reservoir itself taking fire by a *retour de flamme* from the motor. During five years, I may here say in passing, I enjoyed complete immunity from the *retour de flamme* (sucking back of the flame). Then, in the same week in which Mr Vanderbilt burned himself so severely, 6th July 1908, the

same accident overtook me in my little "No. 9" runabout air-ship just as I was crossing the Seine to land on the Ile de Puteaux. I promptly extinguished the flame with my Panama hat . . . without other incident.

For reasons like these I went up on my first air-ship trip without fear of fire, but not without doubt of a possible explosion due to insufficient working of my balloon's escape valves. Should such a "cold" explosion occur, the flame-spitting motor would probably ignite the mass of mixed hydrogen and air that would surround me; but it would have no decisive influence on the result. The "cold" explosion itself would doubtless be sufficient. . . .

Now, after five years of experience, and in spite of the *retour de flamme* above the Ile de Puteaux, I continue to regard the danger from fire as practically *nil*; but the possibility of a "cold" explosion remains always with me, and I must continue to purchase immunity from it at the cost of vigilant attention to my gas escape valves. Indeed, the possibility of the thing is greater technically now than in the early days which I describe. My first air-ship was not built for speed — consequently, it needed very little

"No. 9" CATCHES FIRE OVER THE ILE DE PUTEAUX

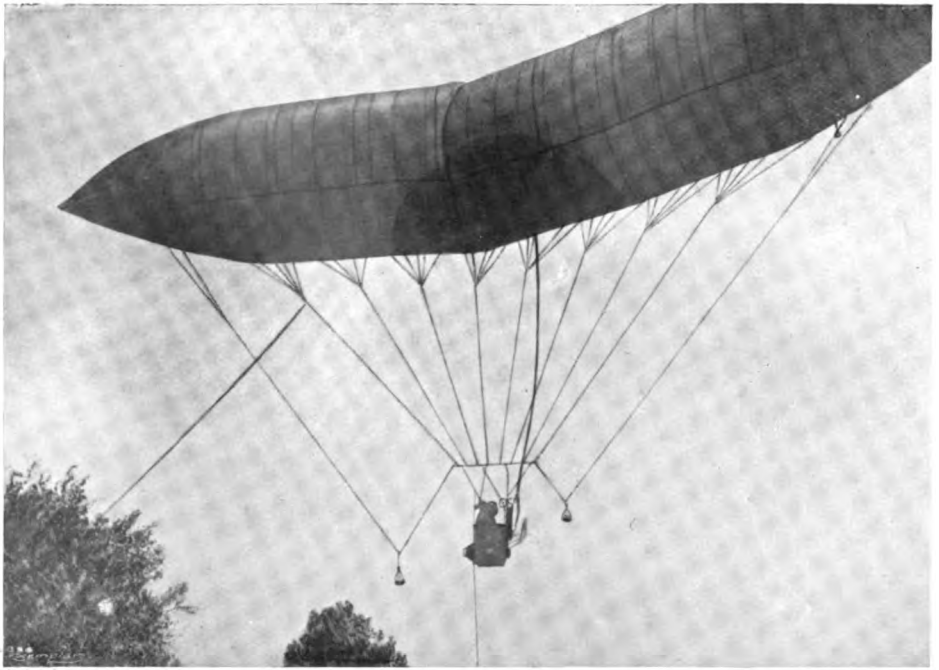
interior pressure to preserve the shape of its balloon. Now that I have great speed, as in my "No. 7," I must have enormous interior pressure to withstand the exterior pressure of the atmosphere in front of the balloon as I drive against it.

CHAPTER X

I GO IN FOR AIRSHIP BUILDING

In the early spring of 1899 I built another airship, which the Paris public at once called "The Santos-Dumont No. 2." It had the same length and, at first sight, the same form as the "No. 1"; but its greater diameter brought its volume up to 200 cubic metres—over 7000 cubic feet—and gave me 20 kilogrammes (44 lbs.) more ascensional force. I had taken account of the insufficiency of the air pump that had all but killed me, and had added a little aluminium ventilator to make sure of permanency in the form of the balloon.

This ventilator was a rotary fan, worked by the motor, to send air into the little interior air balloon, which was sewed inside to the bottom of the great balloon like a kind of closed pocket. In Fig. 5 *G* is the great balloon filled with hydrogen gas, *A* the interior air balloon, *VV* the automatic gas valves, *AV* the latter's air valve, and *TV* the



ACCIDENT TO "No. 2," MAY 11, 1899
(FIRST PHASE)

tube by which the rotary ventilator fed the interior air balloon.

The air valve *AV* was an exhaust valve similar to the two gas valves *VV* in the great balloon,

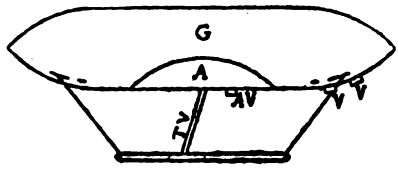


Fig. 5

with the one exception that it was weaker. In this way, when there happened to be too much fluid (*i.e.* gas or air, or both) distending the great balloon, all the air would leave the interior balloon before any of the gas would leave the great balloon.

The first trial of my "No. 2" was set for 11th May 1899. Unfortunately, the weather, which had been fine in the morning, grew steadily rainy in the afternoon. In those days I had no balloon house of my own. All the morning the balloon had been slowly filling with hydrogen gas at the captive balloon station of the Jardin d'Acclimatation. As there was no shed there for me the work had to be done in the open, and it was done vexatiously, with a hundred delays, surprises, and excuses.

When the rain came on, it wetted the balloon. What was to be done? I must either empty it and lose the hydrogen and all my time and trouble, or go on under the disadvantage of a rain-soaked balloon envelope, heavier than it ought to be.

I chose to go up in the rain. No sooner had I risen than the weather caused a great contraction of the hydrogen, so that the long cylindrical balloon shrunk visibly. Then before the air pump could remedy the fault, a strong wind gust of the rainstorm doubled it up worse than the "No. 1," and tossed it into the neighbouring trees.

My friends began at me again, saying:

"This time you have learned your lesson. You must understand that it is impossible to keep the shape of your cylindrical balloon rigid. You must not again risk your life by taking a petroleum motor up beneath it."

I said to myself:

"What has the rigidity of the balloon's form to do with danger from a petroleum motor? Errors do not count. I have learned my lesson, but it is not that lesson."

Accordingly I immediately set to work on a "No. 3," with a shorter and very much thicker balloon, 20 metres (66 feet) long and 7·50 metres

ACCIDENT TO "No. 2," MAY 11, 1899
(SECOND PHASE)

(25 feet) at its greatest diameter (Fig. 6). Its much greater gas capacity—500 cubic metres (17,650 cubic feet)—would give it, with hydrogen, three times the lifting power of my first, and twice that of my second air-ship. This permitted me to use common illuminating gas, whose lifting power is about half that of hydrogen. The hydrogen

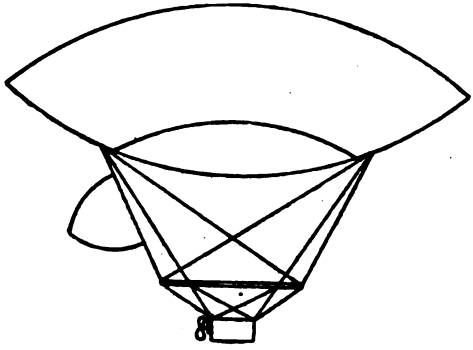


Fig. 6

plant of the Jardin d'Acclimatation had always served me badly. With illuminating gas I should be free to start from the establishment of my balloon constructor or elsewhere as I desired.

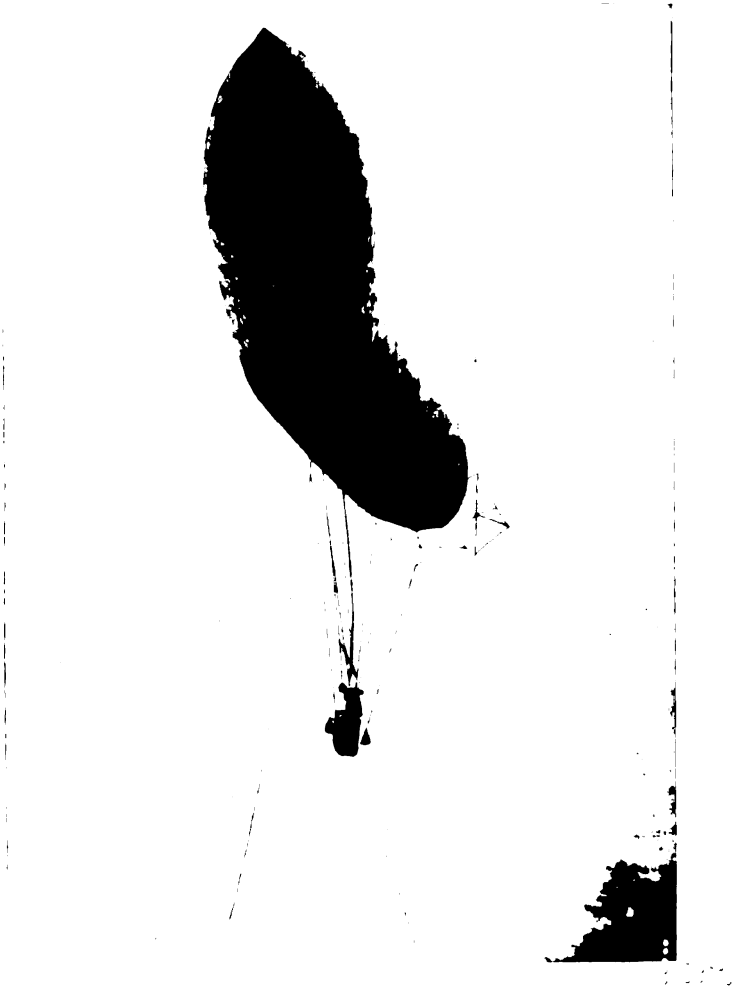
It will be seen that I was getting far away from the cylindrical shapes of my first two balloons. In the future I told myself that I would at least avoid doubling up. The rounder form of this balloon

also made it possible to dispense with the interior air balloon and its feeding air pump that had twice refused to work adequately at the critical moment. Should this shorter and thicker balloon need aid to keep its form rigid I relied on the stiffening effect of a 10-metre (33-foot) bamboo pole Fig. 6) fixed lengthwise to the suspension cords above my head and directly beneath the balloon.

While not yet a true keel, this pole keel supported basket and guide rope and brought my shifting weights into much more effectual play.

On November 13th, 1899, I started in the "Santos-Dumont No. 8," from the establishment of Vaugirard, on the most successful flight that I had yet made.

From Vaugirard I went directly to the Champ de Mars, which I had chosen for its clear, open space. There I was able to practise aerial navigation to my heart's content—circling, driving ahead in straight courses, forcing the air-ship diagonally onward and upward, and shooting diagonally downward, by propeller force, and thus acquiring mastery of my shifting weights. These, because of the greater distance they were now set apart at the extremities of the pole keel (Fig. 6), worked with an effectiveness that astonished even myself.



ACCIDENT TO "No. 2," MAY 11, 1899
(THIRD PHASE

This proved my greatest triumph, for it was already clear to me that the central truth of dirigible ballooning must be ever: "To descend without sacrificing gas and to mount without sacrificing ballast."

During these first evolutions over the Champ de Mars I had no particular thought of the Eiffel Tower. At most it seemed a monument worth going round, and so I circled round it at a prudent distance again and again. Then—still without any dream of what the future had in store for me—I made a straight course for the Parc des Princes, *over almost the exact line that, two years later, was to mark the Deutsch prize route.*

I steered to the Parc des Princes because it was another fine open space. Once there, however, I was loth to descend, so, making a hook, I navigated to the manœuvre grounds of Bagatelle, where I finally landed, in souvenir of my fall of the year previous. It was almost at the exact spot where the kite-flying boys had pulled on my guide rope and saved me from a bad shaking-up. At this time, remember, neither the Aéro Club nor myself possessed a balloon park or shed from which to start and to which to return.

On this trip I considered that had the air been calm my speed in relation to the ground would have been as much as 25 kilometres (15 miles) per hour. In other words, I went at that rate through the air, the wind being strong though not violent. Therefore, even had not sentimental reasons led me to land at Bagatelle, I should have hesitated to return *with the wind* to the Vaugirard balloon house—itself of small size, and difficult of access, and surrounded by all the houses of a busy quarter. Landing in Paris, in general, is dangerous for any kind of balloon, amid chimney-pots that threaten to pierce its belly, and tiles that are always ready to be knocked down on the heads of passers-by. When in the future air-ships become as common as automobiles are at present, spacious public and private landing-stages will have to be built for them in every part of the capital. Already they have been foretold by Mr Wells in his strange book, "When the Sleeper Wakes."

Considerations of this order made it desirable for me to have a plant of my own. I needed a building for the housing of my air-ship between trips. Heretofore I had emptied the balloon of all its gas at the end of each trip, as one is bound to do with spherical balloons. Now I saw very

ACCIDENT TO "No. 2," MAY 11, 1899
(FINALE)

different possibilities for dirigibles. The significant thing was the fact that my "No. 3" had lost so little gas (or, perhaps, none at all) at the end of its first long trip that I could well have housed it overnight and gone out again in it the next day.

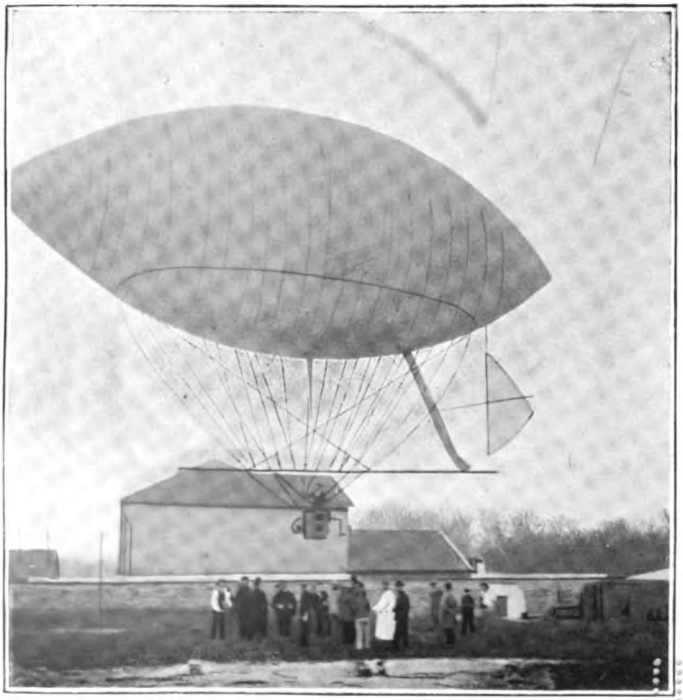
I had no longer the slightest doubt of the success of my invention. I foresaw that I was going into air-ship construction as a sort of life work. I should need my own workshop, my own balloon house, hydrogen plant, and connection with the illuminating gas mains.

The Aéro Club had just acquired some land on the newly-opened Côteaux de Longchamps at St Cloud, and I concluded to build on it a great shed, long and high enough to house my air-ship with its balloon fully inflated, and furnished with all the facilities mentioned.

This aerodrome, which I built at my own expense, was 30 metres long (100 feet), 7 metres (25 feet) wide, and 11 metres (36 feet) high. Even here I had to contend with the conceit and prejudice of artisans which had already given me so much trouble at the Jardin d'Acclimatation. It was declared that the sliding doors of my aerodrome could not be made to slide on

account of their great size. I had to insist. "Follow my directions," I said, "and do not concern yourselves with their practicability!" Although the men had named their own pay, it was a long time before I could get the better of this vainglorious stubbornness of theirs. When finished the doors worked, naturally. Three years later the aerodrome built for me by the Prince of Monaco on my plans had still greater sliding doors.

While this first of my balloon houses was under construction, I made a number of other successful trips in the "No. 8," the last time losing my rudder and luckily landing on the plain at Ivry. I did not repair the "No. 8." Its balloon was too clumsy in form and its motor was too weak. I had now my own aerodrome and gas plant. I would build a new air-ship, and with it I would be able to experiment for longer periods and with more method.



START OF "No. 3," NOVEMBER 13, 1909

CHAPTER XI

THE EXPOSITION SUMMER

THE Exposition of 1900, with its learned congresses, was now approaching. Its International Congress of Aeronautics being set for the month of September I resolved that the new air-ship should be ready to be shown to it.

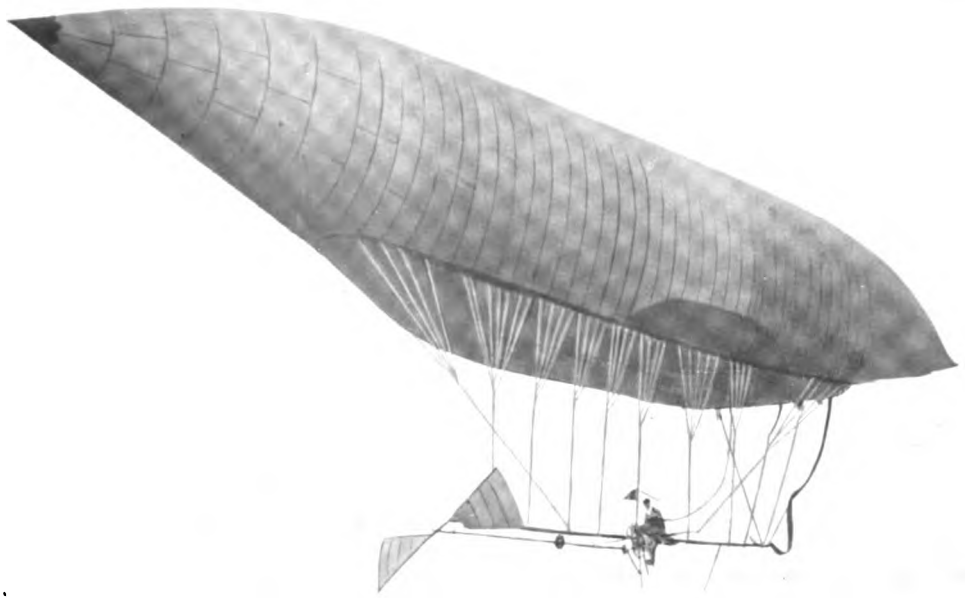
This was my "No. 4," finished 1st August 1900, and by far the most familiar to the world at large of all my air-ships. This is due to the fact that when I won the Deutsch prize, nearly eighteen months later and in quite a different construction, the newspapers of the world came out with old cuts of this "No. 4," which they had kept on file.

It was the air-ship with the bicycle saddle. In it the 10-metre (33-foot) bamboo pole of my "No. 3" came nearer to being a real keel in that it no longer hung above my head, but, amplified by vertical and horizontal cross pieces and a system of tightly-stretched cords, sus-

tained within itself motor, propeller, and connecting machinery, petroleum reservoir, ballast, and navigator in a kind of spider web without a basket (see photograph, page 135).

I was obliged to sit in the midst of the spider web below the balloon on the saddle of a bicycle frame which I had incorporated into it. Thus the absence of the traditional balloon basket appeared to leave me astride a pole in the midst of a confusion of ropes, tubes, and machinery. Nevertheless, the device was very handy, because round this bicycle frame I had united cords for controlling the shifting weights, for striking the motor's electric spark, for opening and shutting the balloon's valves, for turning on and off the water-ballast spigots and certain other functions of the air-ship. Under my feet I had the starting pedals of a new 7 horse-power petroleum motor, driving a propeller with two wings 4 metres (13 feet) across each. They were of silk, stretched over steel plates, and very strong. For steering, my hands reposed on the bicycle handle-bars connected with my rudder.

Above all this there stretched the balloon, 89 metres (129 feet) long, with a middle diameter of 5·10 metres (17 feet) and a gas capacity of



"SANTOS-DUMONT No. 4"

420 cubic metres (nearly 15,000 cubic feet). In form it was a compromise between the slender cylinders of my first constructions and the clumsy compactness of the "No. 3." (See Fig. 7.) For this reason I thought it prudent to give it an interior compensating air balloon fed by a rotary ventilator like that of the "No. 2," and

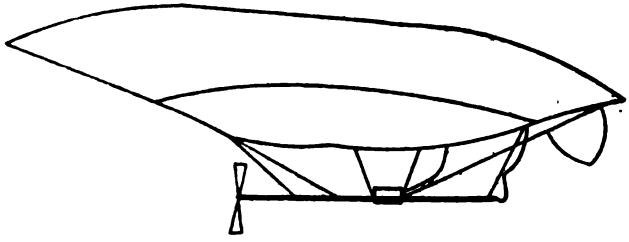


Fig. 7

as the balloon was smaller than its predecessor I was obliged to return again to hydrogen to get sufficient lifting power. For that matter, there was no longer any reason why I should not employ hydrogen. I now had my own hydrogen gas generator, and my "No. 4," safely housed in the aerodrome, might be kept inflated during weeks.

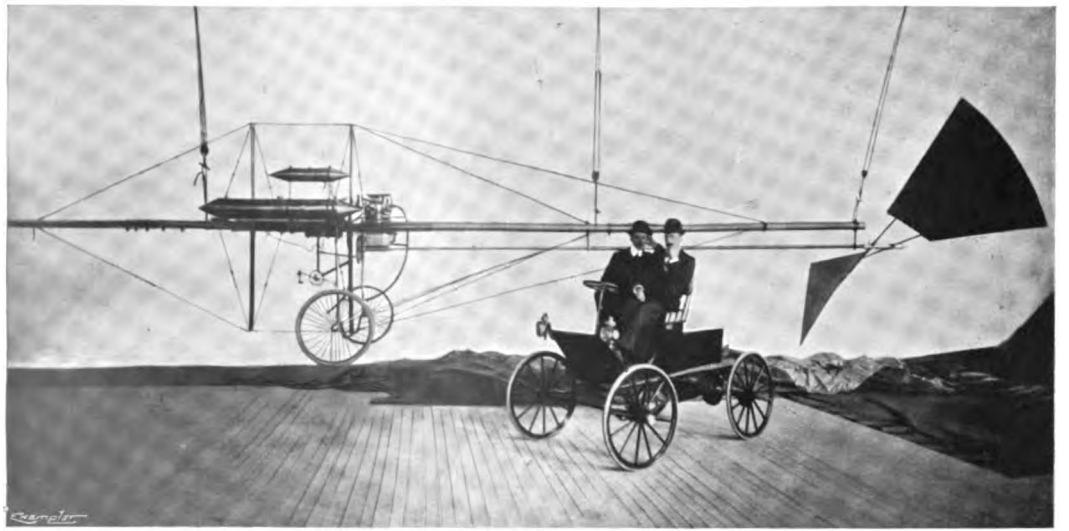
In the "Santos-Dumont, No. 4," I also tried the experiment of placing the propeller at the stem instead of the stern of the air-ship. So, attached to the pole keel in front, the screw pulled,

instead of pushing it through the air. The new 7 horse-power motor with two cylinders turned it with a velocity of 100 revolutions per minute, and produced, from a fixed point, a traction effort of some 30 kilogrammes (66 lbs.).

The pole keel with its cross pieces, bicycle frame, and mechanism weighed heavy. Therefore, although the balloon was filled with hydrogen, I could not take up more than 50 kilogrammes (110 lbs.) of ballast.

I made almost daily experiments with this new air-ship during August and September 1900 at the Aéro Club's grounds at St Cloud, but my most memorable trial with it took place on 19th September in presence of the members of the International Congress of Aeronautics. Although an accident to my rudder at the last moment prevented me from making a free ascent before these men of science I, nevertheless, held my own against a very strong wind that was blowing at the time, and gave what they were good enough to proclaim a satisfying demonstration of the effectiveness of an aerial propeller driven by a petroleum motor.

A distinguished member of the Congress, Professor Langley, desired to be present a few days



MOTOR OF "No. 4"

later at one of my usual trials, and from him I received the heartiest kind of encouragement.

The result of these trials was, nevertheless, to decide me to double the propeller's power by the adoption of the four-cylinder type of petroleum motor without water jacket—that is to say, the system of cooling *à ailettes*. The new motor was delivered to me very promptly, and I immediately set about adapting the air-ship to it. Its extra weight demanded either that I should construct a new balloon or else enlarge the old one. I tried the latter course. Cutting the balloon in half I had a piece put in it, as one puts a leaf in an extension table. This brought the balloon's length to 88 metres (109 feet). Then I found that the aerodrome was too short by 8 metres (10 feet) to receive it. In prevision of future needs I added 4 metres (13 feet) to its length.

Motor, balloon, and shed were all transformed in fifteen days. The Exposition was still open, but the autumn rains had set in. After waiting, with the balloon filled with hydrogen, through two weeks of the worst possible weather I let out the gas and began experimenting with the motor and propeller. It was not lost time, for, bringing the speed of the propeller up to 140 revolutions

per minute, I realised, from a fixed point, a traction effort of 55 kilogrammes (120 lbs.). Indeed, the propeller turned with such force that I took pneumonia in its current of cold air.

I betook myself to Nice for the pneumonia, and there, while convalescing, an idea came to me.

This new idea took the form of my first true air-ship keel.

In a small carpenter shop at Nice I worked it out with my own hands—a long, triangular-sectioned pine framework of great lightness and rigidity. Though 18 metres (59½ feet) in length it weighed only 41 kilogrammes (90 lbs.). Its joints were in aluminium, and, to secure its lightness and rigidity, to cause it to offer less resistance to the air and make it less subject to hygrometric variations, it occurred to me to reinforce it with tightly-drawn piano wires instead of cords.

Then what turned out to be an utterly new idea in aeronautics followed. I asked myself why I should not use this same piano wire for all my dirigible balloon suspensions in place of the cords and ropes used in all kinds of balloons up to this time. I did it, and the innovation turned out to be peculiarly valuable. These piano wires, $\frac{8}{10}$ths

VISIT OF PROFESSOR LANGLEY

of a millimetre (0·032 inch) in diameter, possess a high coefficient of rupture and a surface so slight that their substitution for the ordinary cord suspensions constitutes a greater progress than many a more showy device. Indeed, it has been calculated that the cord suspensions offered almost as much resistance to the air as did the balloon itself.

At the stern of this air-ship keel I again established my propeller. I had found no advantage result from placing it in front of the "No. 4," where it was an actual hindrance to the free working of the guide rope. The propeller was now driven by a new 12 horse-power four-cylinder motor without water jacket, through the intermediary of a long, hollow steel shaft. Placing this motor in the centre of the keel I balanced its weight by taking my position in my basket well to the front, while the guide rope hung suspended from a point still farther forward (Fig. 8). To it, some distance down its length, I fastened the end of a lighter cord run up to a pulley fixed in the after part of the keel, and thence to my basket, where I fastened it convenient to my hand. Thus I made the guide rope do the work of shifting weights. Imagine, for example, that going on

a straight horizontal course (as in Fig. 8) I should desire to rise. I would have but to pull in the guide rope shifter. It would pull the guide rope itself back (Fig. 9), and thus shift back the centre of gravity of the whole system that much. The stem of the air-ship would rise (as in Fig. 9), and,

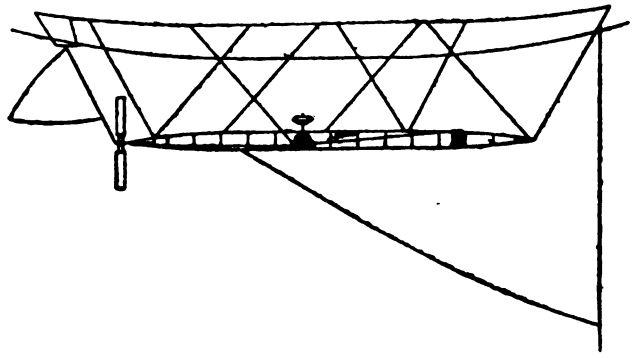
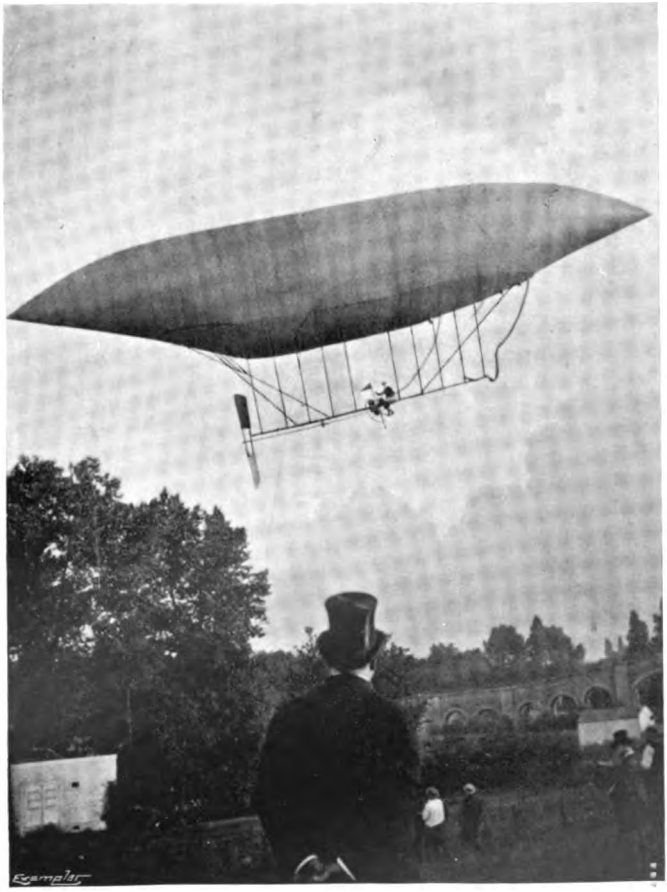


Fig. 9

consequently, my propeller force would push me up along the new diagonal line.

The rudder was fixed at the stern as usual, and water-ballast cylinders, accessory shifting weights, petroleum reservoir, and the other parts of the machinery, were disposed in the new keel, well balanced. For the first time in these experiments, as well as the first time in aeronautics, I used liquid ballast. Two brass reservoirs, very thin,



"No. 4." FLIGHT BEFORE PROFESSOR LANGLEY

and holding altogether 54 litres (12 gallons), were filled with water and fixed in the keel, as above stated, between motor and propeller, and their two spigots were so arranged that they could be

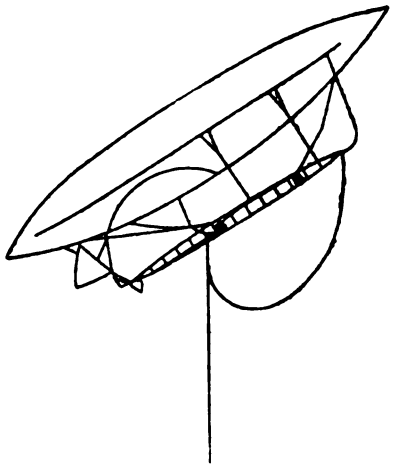


Fig. 9

opened and shut from my basket by means of two steel wires.

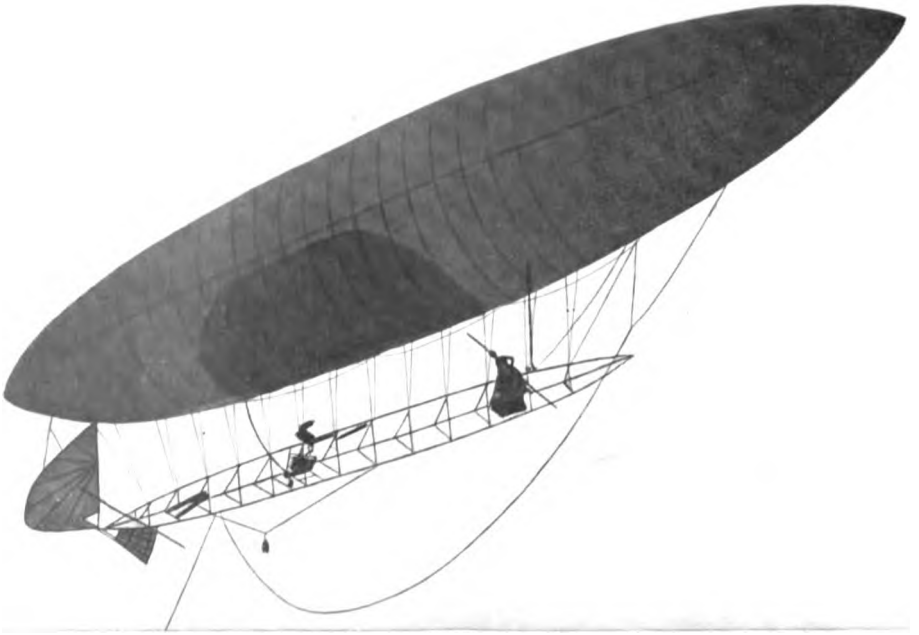
Before this new keel was fitted to the enlarged balloon of my "No. 5," and in acknowledgment of the work I had done in 1900, the Scientific Commission of the Paris Aéro Club had awarded me its Encouragement prize, founded by M. Deutsch (de la Meurthe), and consisting of the

yearly interest on 100,000 francs. To induce others to follow up the difficult and expensive problem of dirigible ballooning I left this 4000 francs at the disposition of the Aéro Club to found a new prize. I made the conditions of winning it very simple:

"The Santos-Dumont prize shall be awarded to the aeronaut, a member of the Paris Aéro Club, and not the founder of this prize, who between 1st May and 1st October 1901, starting from the Parc d'Aerostation of St Cloud, shall turn round the Eiffel Tower and come back to the starting-point, at the end of whatever time, without having touched ground, and by his self-contained means on board alone.

"If the Santos-Dumont prize is not won in 1901 it shall remain open the following year, always from 1st May to 1st October, and so on, until it be won."

The Aéro Club signified the importance of such a trial by deciding to give its highest reward, a gold medal, to the winner of the Santos-Dumont prize, as may be seen by its minutes of the time. Since then the 4000 francs have remained in the treasury of the Club.



"SANTOS-DUMONT No. 5"

CHAPTER XII

THE DEUTSCH PRIZE AND ITS PROBLEMS

THIS brings me to the Deutsch prize of aerial navigation, offered in the spring of 1900, while I was navigating my "No. 3," and after I had on at least one occasion—all unknowing—steered over what was to be its exact course from the Eiffel Tower to the Seine at Bagatelle (see page 127).

This prize of 100,000 francs, founded by M. Deutsch (de la Meurthe), a member of the Paris Aéro Club, was to be awarded by the Scientific Commission of that organisation to the first dirigible balloon or air-ship that between 1st May and 1st October 1900, 1901, 1902, 1903, and 1904 should rise from the Parc d'Aerostation of the Aéro Club at St Cloud and, without touching ground and by its own self-contained means on board alone, describe a closed curve in such a way that the axis of the Eiffel Tower should be within the interior of the circuit, and return to the point of departure in the maximum time of half-an-hour.

Should more than one accomplish the task in the same year the 100,000 francs were to be divided in proportion to the respective times.

The Aéro Club's Scientific Commission had been named expressly for the purpose of formulating these and such other conditions of the foundation as it might deem proper, and by reason of certain of them I had made no attempt to win the prize with my "Santos-Dumont, No. 4." The course from the Aéro Club's Parc d'Aerostation to the Eiffel Tower and return was 11 kilometres (nearly 7 miles), and this distance, *plus the turning round the Tower*, must be accomplished in thirty minutes. This meant in a perfect calm a necessary speed of 25 kilometres (15½ miles) per hour for the straight stretches—a speed I could not be sure to maintain all the way in my "No. 4."

Another condition formulated by the Scientific Commission was that its members, who were to be the judges of all trials, must be notified twenty-four hours in advance of each attempt. Naturally, the operation of such a condition would be to nullify as much as possible all minute time calculations based either on a given rate of speed through perfect calm or such air current as might be prevailing twenty-four hours previous to the

hour of trial. Though Paris is situated in a basin, surrounded on all sides by hills, its air currents are peculiarly variable, and brusque meteorological changes are extremely common.

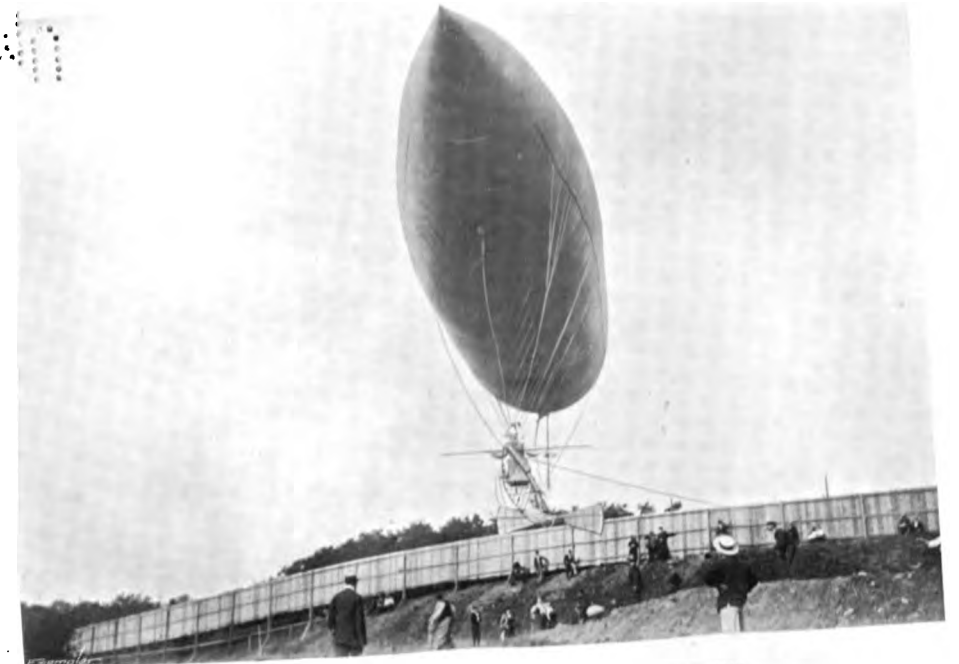
I foresaw also that when a competitor had once committed the formal act of assembling a Scientific Commission on a slope of the River Seine so far away from Paris as St Cloud he would be under a kind of moral pressure to go on with his trial, no matter how the air currents might have increased, and no matter in what kind of weather—wet, dry, or simply humid—he might find himself.

Again, this moral pressure to go on with the trial against the aeronaut's better judgment must extend even to the event of an unlucky change in the state of the air-ship itself. One does not convoke a body of prominent personages to a distant riverside for nothing, yet in the twenty-four hours between notification and trial even a well-watched elongated balloon might well lose a little of its tautness unperceived. A previous day's preliminary trial might easily derange so uncertain an engine as the petroleum motor of the year 1900. And, finally, I saw that the competitor would be barred by common courtesy from convoking the Commission at the very hour most

favourable for dirigible balloon experiments over Paris—the calm of the dawn. The duellist may call out his friends at that sacred hour, but not the air-ship captain.

In founding the Santos-Dumont prize with the 4000 francs awarded to me by the Aéro Club for my work in the year 1900 it will be observed that I made no such conditions by the way. I did not wish to complicate the trial by imposing a minimum velocity, the check of a special committee, or any limitation of time of trial during the day. I was sure that even under the widest conditions it would be a great deal to come back to the starting-point after having reached a post publicly pointed out in advance—a thing that was unheard of before the year 1901.

The conditions of the Santos-Dumont prize, therefore, left competitors free to choose the state of the air least unfavourable to them, as the calm of late evening or early morning. Nor would I inflict on them the possible surprises of a period of waiting between the convocation and the meeting of a Scientific Commission, itself in my eyes quite unnecessary in these days, when the army of newspaper reporters of a great capital is always ready to mobilise without notice, at any hour



"No. 5." LEAVING AËRO CLUB GROUNDS, JULY 12, 1901

and spot, on the bare prospect of news. The newspaper men of Paris would be my Scientific Commission.

As I had excluded myself from trying for the Santos-Dumont prize I naturally wished to show that it would not be impossible to fulfil its conditions. My "No. 5"—composed of the enlarged balloon of the "No. 4" and the new keel, motor, and propeller already described—was now ready for trial. In it, on the first attempt, I fulfilled the conditions of my own prize foundation.

This was on July 12th, 1901, after a practice flight the day before. At 4.30 A.M. I steered my air-ship from the park of the Aéro Club at St Cloud to the Longchamps racecourse. I did not at that moment take time to ask permission of the Jockey Club, which, however, a few days later placed that admirable open space at my disposition. Ten times in succession I made the circuit of Longchamps, stopping each time at a point designed beforehand.

After these first evolutions, which altogether made up a distance of about 35 kilometres (22 miles), I set out for Puteaux, and after an excursion of about 8 kilometres (2 miles), done in nine minutes, I steered back again to Longchamps.

I was by this time so well satisfied with the dirigibility of my "No. 5" that I began looking for the Eiffel Tower. It had disappeared in the mists of the morning, but its direction was well known to me, so I steered for it as well as I might.

In ten minutes I had come within 200 metres (40 rods) of the Champ de Mars. At this moment one of the cords managing my rudder broke. It was absolutely necessary to repair it at once, and to repair it I must descend to earth. With perfect ease I pulled forward the guide rope, shifted my centre of gravity, and drove the airship diagonally downward, landing gently in the Trocadero Gardens. Good-natured workmen ran to me from all directions.

Did I need anything? they asked.

Yes; I needed a ladder. And in less time than it takes to write it a ladder was found and placed in position. While two of these discreet and intelligent volunteers held it I climbed some twenty rounds to its top, and was able to repair the damaged rudder connection.

I started off again, mounting diagonally to my chosen altitude, turned the Eiffel Tower in a wide curve, and returned to Longchamps in a

"No. 5." RETURNING FROM THE EIFFEL TOWER

straight course without further incident after a trip which, including the stop for repairs, had lasted one hour and six minutes. Then after a few minutes' conversation I took my flight back to the St Cloud Aerodrome, passing the Seine at an altitude of 200 metres (over 600 feet), and housing the still perfectly-inflated air-ship in its shed as though it were a simple automobile.

CHAPTER XIII

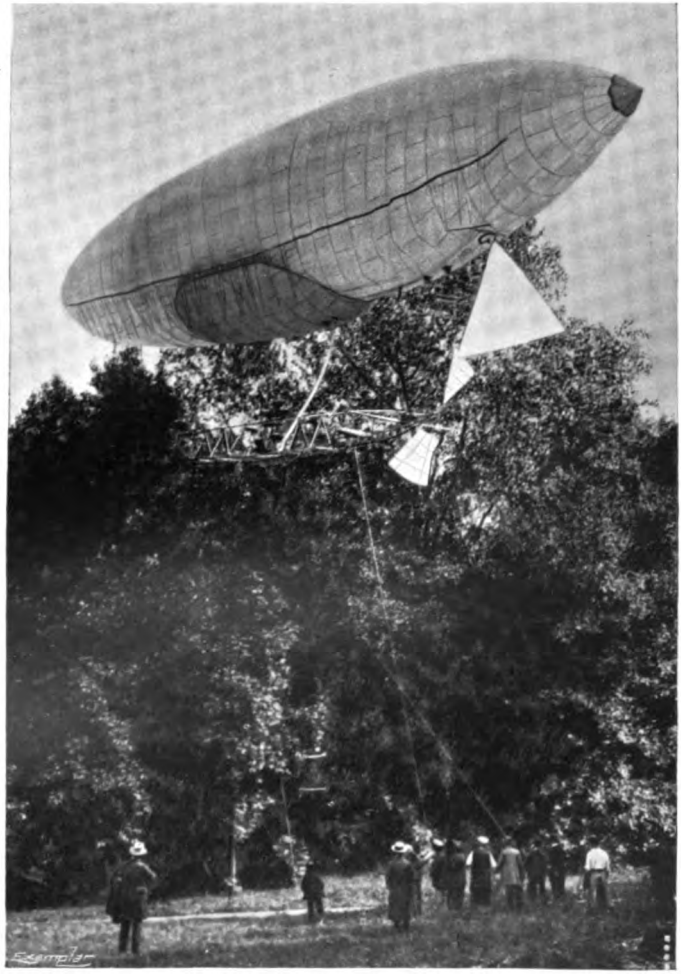
A FALL BEFORE A RISE

My "No. 5" had proved itself so much more powerful than its predecessors that I now found courage to inscribe myself for the Deutsch prize competition.

Having taken this decisive step I at once convoked the Scientific Commission of the Aéro Club for a trial in accordance with the regulations.

The Commission assembled in the grounds of the Aéro Club at St Cloud on July 13th, 1901 at 6.30 A.M. At 6.41 I started off. I turned the Eiffel Tower in the tenth minute and came back against an unexpected head wind, reaching the timekeepers at St Cloud in the fortieth minute, at an altitude of 200 metres, and after a terrific struggle with the element.

Just at this moment my capricious motor stopped, and the air-ship, bereft of its power, was carried off, and fell on the tallest chestnut-tree in



"No. 5." ACCIDENT IN THE PARK OF M. EDMOND DE ROTHSCHILD

the park of M. Edmond de Rothschild. The inhabitants and servants of the villa, who came running, very naturally imagined that the air-ship must be wrecked and myself probably hurt. They were astonished to find me standing in my basket high up in the tree, while the propeller touched the ground. Considering the force with which the wind had blown when I was battling with it on the home stretch I was myself surprised to note how little the balloon was torn. Nevertheless, all its gas had left it.

This happened very near the house of the Princess Isabel, Comtesse d'Eu, who, hearing of my plight, and learning that I must be occupied some time in disengaging the air-ship, sent a lunch to me up in my tree, with an invitation to come and tell her the story of my trip. When the story was finished the daughter of Dom Pedro said to me:

"Your evolutions in the air make me think of the flight of our great birds of Brazil. I hope you will do as well with your propeller as they do with their wings, and that you will succeed for the glory of our common country."

A few days later I received the following letter:—

"1*st August* 1901.

"MONSIEUR SANTOS-DUMONT,—Here is a medal of St Benedict that protects against accidents.

"Accept it, and wear it at your watch-chain, in your card-case, or at your neck.

"I send it to you, thinking of your good mother, and praying God to help you always and to make you work for the glory of our country.

(Signed) "ISABEL, COMTESSE D'EU."

As the newspapers have often spoken of my "bracelet" I may say that the thin gold chain of which it consists is simply the means I have taken to wear this medal, which I prize.

The air-ship, as a whole, was damaged very little, considering the force of the wind and the nature of the accident. When it was ready to be taken out again I nevertheless thought it prudent to make several trials with it over the grassy lawn of the Longchamps racecourse. One of these trials I will mention, because it gave me—something rare—a fairly accurate idea of the air-ship's speed in perfect calm. On this occasion Mr Maurice Farman followed me round the racecourse in his automobile at its second speed. His estimate was between 26 and 30 kilometres (16

AN ACCIDENT

and 18½ miles) per hour with my guide rope dragging. Of course, when the guide rope drags it acts exactly like a brake. How much it holds one back depends upon the length that actually drags along the ground. Our calculation at the time was about 5 kilometres (3 miles) per hour, which would have brought my proper speed up to between 30 and 35 kilometres (18½ and 21½ miles) per hour. All this encouraged me to make another trial for the Deutsch prize.

And now I come to a terrible day—8th August 1901. At 6.30 A.M., in presence of the Scientific Commission of the Aéro Club, I started again for the Eiffel Tower.

I turned the Tower at the end of nine minutes and took my way back to St Cloud; but my balloon was losing hydrogen through one of its two automatic gas valves, whose spring had been accidentally weakened.

I had perceived the beginning of this loss of gas even before reaching the Eiffel Tower, and ordinarily, in such an event, I should have come at once to earth to examine the lesion. But here I was competing for a prize of great honour, and my speed had been good. Therefore I risked going on.

The balloon now shrunk visibly. By the time I had got back to the fortifications of Paris, near La Muette, it caused the suspension wires to sag so much that those nearest to the screw propeller caught in it as it revolved.

I saw the propeller cutting and tearing at the wires. I stopped the motor instantly. Then, as a consequence, the air-ship was at once driven back toward the Tower by the wind, which was strong.

At the same time I was falling. The balloon had lost much gas. I might have thrown out ballast and greatly diminished the fall, but then the wind would have time to blow me back on the Eiffel Tower. I, therefore, preferred to let the air-ship go down as it was going. It may have seemed a terrific fall to those who watched it from the ground, but to me the worst detail was the air-ship's lack of equilibrium. The half-empty balloon, fluttering its empty end as an elephant waves his trunk, caused the air-ship's stem to point upward at an alarming angle. What I most feared, therefore, was that the unequal strain on the suspension wires would break them one by one and so precipitate me to the ground.

Why was the balloon fluttering an empty end

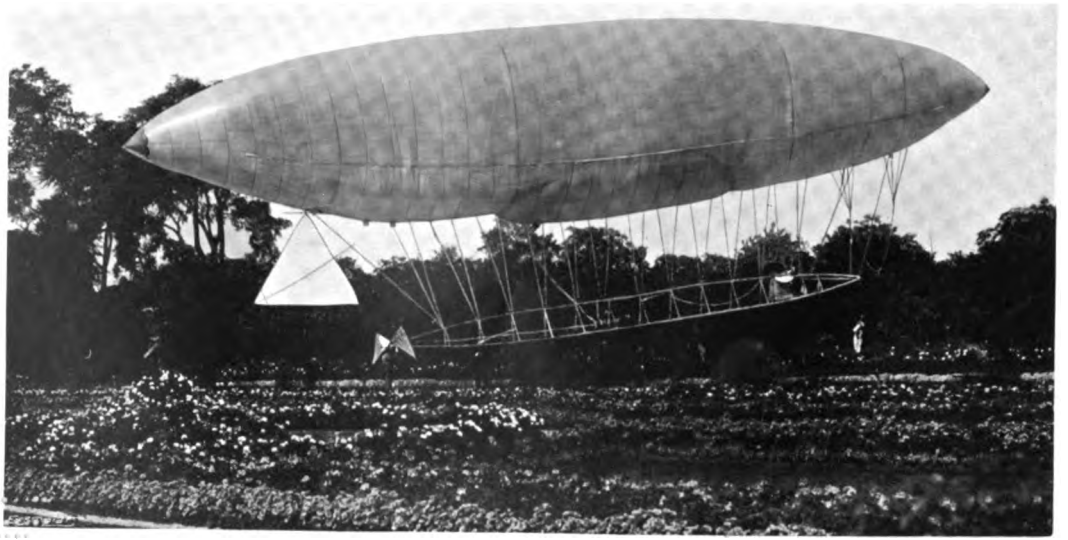
and causing all this extra danger? How was it that the rotary ventilator was not fulfilling its purpose in feeding the interior air balloon and in this manner swelling out the gas balloon around it? The answer must be looked for in the nature of the accident. The rotary ventilator stopped working when the motor itself stopped, and I had been obliged to stop the motor to prevent the propeller from tearing the suspension wires near it when the balloon first began to sag from loss of gas. It is true that the ventilator, which was working at that moment, had not proved sufficient to prevent the first sagging. It may have been that the interior air balloon refused to fill out properly. The day after the accident, when my balloon constructor's man came to me for the plans of a "No. 6" balloon envelope, I gathered from something he said that the interior air balloon of the "No. 5," not having been given time for its varnish to dry before being adjusted, might have stuck together or stuck to the sides or bottom of the outer balloon. Such are the rewards of haste.

I was falling. At the same time the wind was carrying me toward the Eiffel Tower. It had already carried me so far that I was expecting to

land on the Seine embankment beyond the Trocadero. My basket and the whole of the keel had already passed the Trocadero hotels, and had my balloon been a spherical one, it too would have cleared the building. But now, at the last critical moment, the end of the long balloon that was still full of gas came slapping down on the roof just before clearing it. It exploded with a great noise—exactly like a paper bag struck after being blown up. This was the "terrific explosion" described in the newspapers of the day.

I had made a mistake in my estimate of the wind's force by a few yards. Instead of being carried on to fall on the Seine embankment I now found myself hanging in my wicker basket high up in the courtyard of the Trocadero hotels, supported by my air-ship's keel, which stood braced at an angle of about 45 degrees between the courtyard wall above and the roof of a lower construction farther down. The keel, in spite of my weight, that of the motor and machinery, and the shock it had received in falling, resisted wonderfully. The thin pine scantlings and piano wires of Nice had saved my life!

After what seemed tedious waiting I saw a



PHASE OF AN ACCIDENT

rope being lowered to me from the roof above. I held to it, and was hauled up, when I perceived my rescuers to be the brave firemen of Paris. From their station at Passy they had been watching the flight of the air-ship. They had seen my fall, and immediately hastened to the spot. Then, having rescued me, they proceeded to rescue the air-ship.

The operation was painful. The remains of the balloon envelope and the suspension wires hung lamentably, and it was impossible to disengage them except in strips and fragments!

So I escaped—and my escape may have been narrow — but it was not from the particular danger always present in my mind during this period of trials around the Eiffel Tower. A Parisian journalist said that had the Eiffel Tower not existed it would have been necessary to invent it for the needs of aerostation. It is true that the engineers who remain at its summit have at their hands all necessary instruments for observing aerial and meteorological conditions: their chronometers are exact; and, as Professor Langley has said in a communication to the Louisiana Purchase Exposition Committee, the position of the Tower as a central landmark,

visible to everyone from considerable distances, made it a unique winning-post for an aerial contest. I myself had circled round it at a respectful distance, of my own free will, in 1899, before the stipulation of the Deutsch prize competition was dreamed of. Yet none of these considerations altered the other fact that the necessity to round the Eiffel Tower attached a unique element of danger to the task.

What I feared was that in my eagerness to make a quick turning, by some error in steering or by the influence of some unexpected side wind, I might be dashed against the Tower. The impact would certainly burst my balloon, and I should fall to the ground like a stone. Nor could the utmost prudence and self-control in making a wide turn guarantee me against the danger. Should my capricious motor stop as I approached the Tower—exactly as it stopped after I had passed over the timekeepers' heads at St Cloud, returning from my first trial on 13th July 1903—I should be powerless to hold the air-ship back.

Therefore I always dreaded the turn round the Eiffel Tower, looking on it as my principal danger. While never seeking to go high in my air-ships—on the contrary, I hold the record for

the low altitudes in a free balloon—in passing over Paris I must necessarily move above and out of the way of the chimney-pots and steeples. The Eiffel Tower was my one danger, yet it was my winning-post!

Such were my fears while on the ground; while in the air I had no time for fear. I have always kept a cool head. Alone in the air-ship I am always busy, for there is more than enough work for one man. Like the captain of a yacht, I must not let go the rudder for an instant. Like its chief engineer, I must watch the motor. The balloon's rigidity of form must be preserved. And with this capital detail is connected the whole complex problem of the air-ship's altitude, the manœuvring of guide rope and shifting weights, the economising of ballast, and the surveillance of the air pump attached to the motor. Besides all this occupation there is also the strong joy of commanding rapid movement. The pleasurable sensations of aerial navigation experienced in my first air-ships were intensified in the powerful "No. 5." As M. Jaurès has well put it, I now felt myself a man in the air, commanding movement. In my spherical balloons I had felt myself to be only the shadow of a man!

CHAPTER XIV

THE BUILDING OF MY "NO. 6'

On the very evening of my fall to the roof of the Trocadero hotels I gave out the specifications of a "Santos-Dumont, No. 6," and after twenty-two days of continuous labour it was finished and inflated.

The new balloon had the shape of an elongated ellipsoid (Fig. 10), 33 metres (110 feet) by its

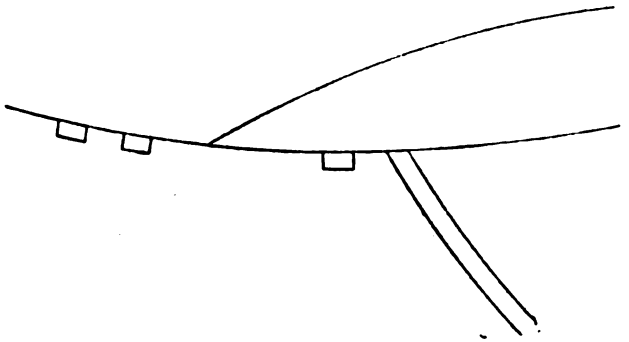
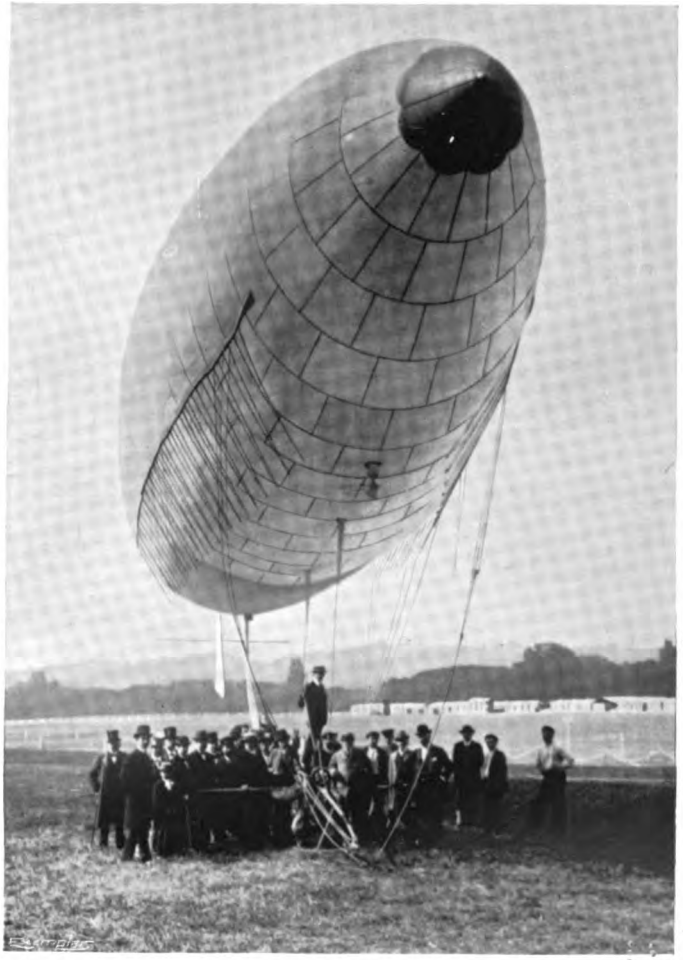


Fig. 10

great axis and 6 metres (20 feet) by its small axis, terminated fore and aft by cones.



"No. 6." FIRST TRIP

I now gave more care than ever to the devices on which I depended to maintain the balloon's rigidity of form. I had fallen to the roof of the Trocadero hotels by the fault of the smallest and most insignificant-looking piece of mechanism of the entire system—a weakened valve that let out the balloon's hydrogen. In very much the same way the fall of the first of all my air-ships had been occasioned by the failure of a little air-pump.

In all my constructions, except the big-bellied balloon of the "No. 3," I had depended much on the interior compensating air balloon (Fig. 5, page 119) fed by air pump or rotary ventilator. Sewed like a closed patch pocket to the inside bottom of the great balloon, this compensating air balloon would remain flat and empty so long as the great balloon remained distended with its gas. Then, as hydrogen might be condensed from time to time by changes of altitude and temperature, the air pump or ventilator worked by the motor would begin to fill the compensating air balloon, make it take up more room inside the great balloon, and so keep the latter distended.

Inside the balloon of my "No. 6" I now sewed such a compensating balloon, capable of holding

60 cubic metres (2118 cubic feet). The ventilator that was to feed it formed practically a part of the motor itself. Revolving continually while the motor worked, it would serve air continually to the compensating balloon whether or not the latter would be able to hold it. What air it could not hold would escape through a comparatively weak valve ("Air Valve," Fig. 10) communicating with the outer atmosphere through the bottom of the air balloon, which was also the bottom of the great outer balloon.

To relieve the great balloon of its dilated hydrogen when necessary I supplied it with two of the best valves I could make ("Gas Valves," Fig. 10). These also communicated with the outer atmosphere. Imagine, now, that after a certain condensation of my hydrogen the interior compensating balloon should have filled up in part with air from the ventilator and so maintained the form of the great balloon rigid. Shortly after, by a change of temperature or altitude, the hydrogen would begin to dilate again. Something would have to give way, or the balloon would burst in a "cold explosion." What ought to give way first? Evidently the weaker air valve ("Air Valve," Fig. 10). Letting out part or all of the air in the

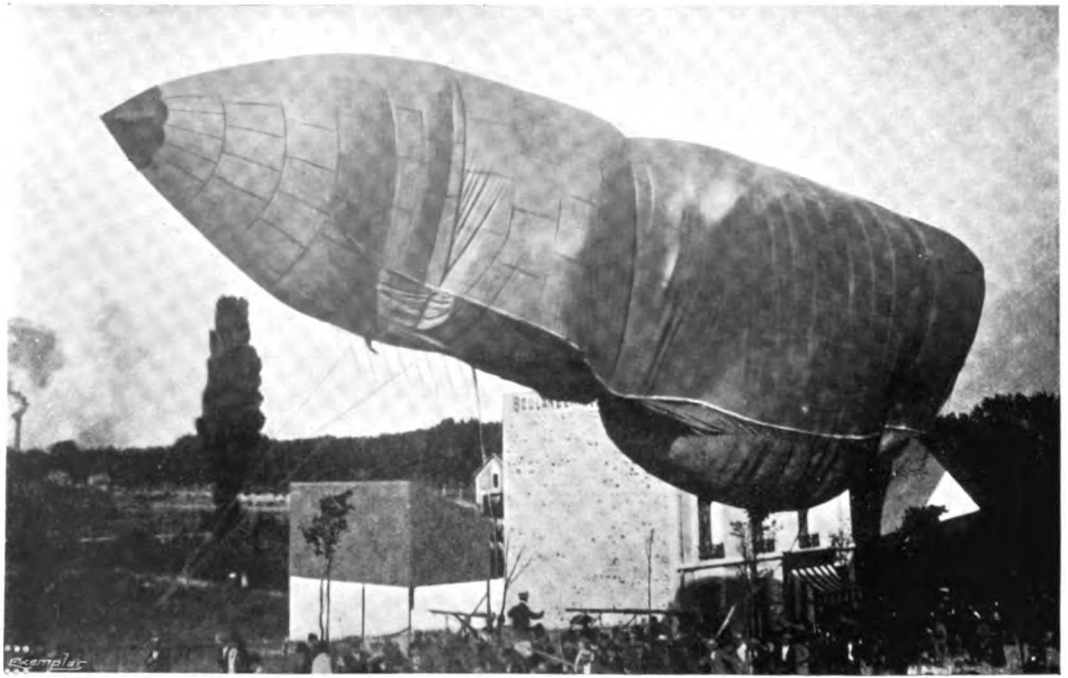
interior balloon, it would relieve the tension of the swelling hydrogen; and only afterwards, should this not be sufficient, would the stronger gas valves (Fig. 10) let out precious hydrogen.

All three valves were automatic, opening outward on a given pressure from within. One of the hypotheses to account for the terrible accident to the unhappy Severo's dirigible "Pax"* is concerned with this all-important problem of valves. The "Pax," as originally constructed, had two. M. Severo, who was not a practical aeronaut, stopped up one of them with wax before starting on his first and last voyage. In view of the decreasing pressure of the atmosphere as one goes higher the ascent of a dirigible should always be slow and never great, for gas will expand on the rise of a few yards. It is quite different from the case of the spherical balloon, which has no interior pressure to withstand. A dirigible whose

* In the early morning of 12th May 1902 M. Augusto Severo, accompanied by his mechanician, Sachet, started from Paris on a first trial with the "Pax," the invention and construction of M. Severo. The "Pax" rose at once to a height almost double that of the Eiffel Tower, when, for reasons not precisely known, it exploded, and came crashing to earth with its two passengers. The fall took eight seconds to accomplish, and the luckless experimenters were picked up broken and shapeless masses.

envelope is distended by great pressure depends on its valves not to burst. With one of its valves stopped with wax the "Pax" was allowed to shoot up from the earth, and immediately its occupants seem to have lost their heads. Instead of checking their rapid rise one of them threw out ballast—a handful of which will send up a great spherical balloon perceptibly. The mechanician of Severo is said to have been last seen throwing out a whole bag in his excitement. Up shot the "Pax" higher and higher, and the expansion, the explosion, and the awful fall came as a chain of consequences.

The tonnage of my new balloon was 630 cubic metres (22,239 cubic feet), affording an absolute lifting power of 690 kilogrammes (1518 lbs.), but the increased weight of the new motor and machinery, nevertheless, put my disposable ballast at 110 kilogrammes (242 lbs.). It was a four-cylinder motor of 12 horse-power, cooled automatically by the circulation of water round the top of the piston (culasse). While the water cooler brought extra weight, I was glad to have it, for the arrangement would permit me to utilise, without fear of overheating or jamming *en route*, the full power of the motor, which was able to



AN ACCIDENT TO "No. 6"

communicate to the propeller a traction effort of 66 kilogrammes (145 lbs.).

My daily practice with the new air-ship ended, 6th September 1901, in a slight accident. The balloon was reinflated by 15th September, but four days later it crashed against a tree in making a too sudden turn. Such accidents I have always taken philosophically, looking on them as a kind of insurance against more terrible ones. Were I to give a single word of caution to all dirigible balloonists, it would be: "Keep close to earth."

The place of the air-ship is not in high altitudes, and it is better to catch in the tops of trees, as I used to do in the Bois de Boulogne, than to risk the perils of the upper air without the slightest practical advantage.

CHAPTER XV

WINNING THE DEUTSCH PRIZE

AND now, 19th October 1901, the air-ship "Santos-Dumont No. 6," having been repaired with great celerity, I tried again for the Deutsch prize and won it.

On the day before the weather had been wretched. Nevertheless, I had sent out the necessary telegrams convoking the Commission. Through the night the weather had improved, but the atmospheric conditions at 2 o'clock in the afternoon—the hour announced for the trial—were, nevertheless, so unfavourable that of the twenty-five members composing the Commission only five made their appearance—MM. Deutsch (de la Meurthe), de Dion, Fonvielle, Besançon, and Aimé.

The Central Meteorological Bureau, consulted at this hour by telephone, reported a south-east wind blowing 6 metres per second at the altitude of the Eiffel Tower. When I consider that I

SCIENTIFIC COMMISSION OF AËRO CLUB AT THE WINNING OF THE DEUTSCH PRIZE

was content when my first air-ship in 1898 had, in the opinion of myself and friends, been going at the rate of 7 metres per second I am still surprised at the progress realised in those three years, for I was now setting out to win a race against a time limit in a wind blowing almost as fast as the highest speed I had realised in my first air-ship.

The official start took place at 2.42 P.M. In spite of the wind striking me sidewise, with a tendency to take me to the left of the Eiffel Tower, I held my course straight to that goal. Gradually I drove the air-ship onward and upward to a height of about 10 metres above its summit. In doing this I lost some time, but secured myself against accidental contact with the Tower as much as possible.

As I passed the Tower I turned with a sudden movement of the rudder, bringing the air-ship round the Tower's lightning conductor at a distance of about 50 metres from it. The Tower was thus turned at 2.51 P.M., the distance of 5½ kilometres, *plus the turning*, being done in nine minutes.

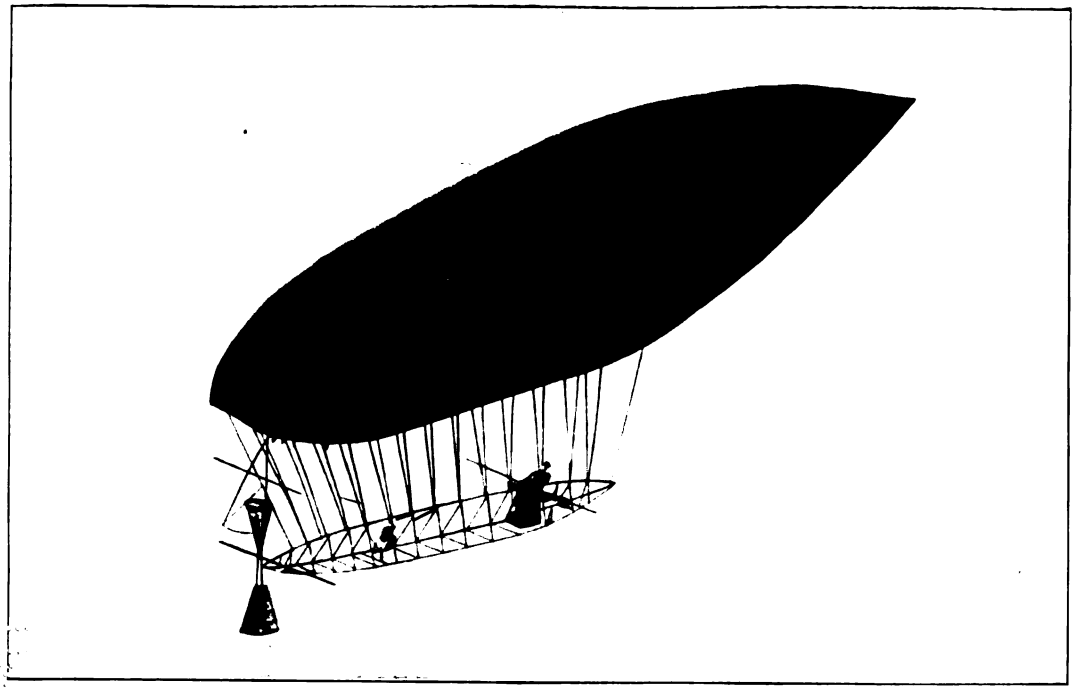
The return trip was longer, being in the teeth of this same wind. Also, during the trip to the

Tower the motor had worked fairly well. Now, after I had left it some 500 metres behind me, the motor was actually on the point of stopping. I had a moment of great uncertainty. I must make a quick decision. It was to abandon the steering wheel for a moment, at the risk of drifting from my course, in order to devote my attention to the carburating lever and the lever controlling the electric spark.

The motor, which had almost stopped, began to work again. I had now reached the Bois, where, by a phenomenon known to all aeronauts, the cool air from the trees began making my balloon heavier and heavier—or in true physics, smaller by condensation. By an unlucky coincidence the motor at this moment began slowing again. Thus the air-ship was descending, while its motive power was decreasing.

To correct the descent I had to throw back both guide rope and shifting weights. This caused the air-ship to point diagonally upward, so that what propeller-force remained caused it to remount continually in the air.

I was now over the crowd of the Auteuil race-track, already with a sharp pointing upward. I heard the applause of the mighty throng, when



"No. 6." MAKING FOR EIFFEL TOWER; ALTITUDE 1000 FEET

suddenly my capricious motor started working at full speed again. The suddenly-accelerated propeller being almost under the high-pointed air-ship exaggerated the inclination, so that the applause of the crowd changed to cries of alarm. As for myself, I had no fear, being over the trees of the Bois, whose soft greenery, as I have already stated, always reassured me.

All this happened very quickly—before I had a chance to shift my weights and guide rope back to the normal horizontal positions. I was now at an altitude of 150 metres. Of course, I might have checked the diagonal mounting of the air-ship by the simple means of slowing the motor that was driving it upward; but I was racing against a time limit, and so I just went on.

I soon righted myself by shifting the guide rope and the weights forward. I mention this in detail because at the time many of my friends imagined something terrible was happening. All the same, I did not have time to bring the air-ship to a lower altitude before reaching the timekeepers in the Aéro Club's grounds—a thing I might easily have done by slowing the motor. This is why I passed so high over the judges' heads.

On my way to the Tower I never looked down

on the house-tops of Paris: I navigated in a sea of white and azure, seeing nothing but the goal. On the return trip I had kept my eyes fixed on the verdure of the Bois de Boulogne and the silver streak of river where I had to cross it. Now, at my high altitude of 150 metres and with the propeller working at full power, I passed above Longchamps, crossed the Seine, and continued on at full speed over the heads of the Commission and the spectators gathered in the Aéro Club's grounds. At that moment it was eleven minutes and thirty seconds past three o'clock, making the time exactly twenty-nine minutes and thirty-one seconds.

The air-ship, carried by the impetus of its great speed, passed on as a racehorse passes the winning-post, as a sailing yacht passes the winning-line, as a road racing automobile continues flying past the judges who have snapped its time. Like the jockey of the racehorse, I then turned and drove myself back to the aérodrome to have my guide rope caught and be drawn down at twelve minutes forty and four-fifths seconds past three, or thirty minutes and forty seconds from the start.

I did not yet know my exact time.

I cried: "Have I won?"

ROUND EIFFEL TOWER

And the crowd of spectators cried back to me: "Yes!"

. . . . . .

For a while there were those who argued that my time ought to be calculated up to the moment of my second return to the aérodrome instead of to the moment when I first passed over it, returning from the Eiffel Tower. For a while, indeed, it seemed that it might be more difficult to have the prize awarded to me than it had been to win it. In the end, however, common-sense prevailed. The money of the prize, amounting in all to 125,000 francs, I did not desire to keep. I, therefore, divided it into unequal parts. The greater sum, of 75,000 francs, I handed over to the Prefect of Police of Paris to be used for the deserving poor. The balance I distributed among my employees, who had been so long with me and to whose devotion I was glad to pay this tribute.

At this same time I received another grand prize, as gratifying as it was unexpected. This was a sum of 100 contos (125,000 francs), voted to me by the Government of my own country, and accompanied by a gold medal of large size and great beauty, designed, engraved, and struck off in Brazil. Its obverse shows my humble self

led by Victory and crowned with laurel by a flying figure of Renown. Above a rising sun there is engraved the line of Camoëns, altered by one word, as I adopted it to float on the long streamer of my air-ship: "Por *ceos* nunca d'antes navegados!" * The reverse bears these words: "Being President of the Republic of the United States of Brazil, the Doctor Manoel Ferraz de Campos Salles has given order to engrave and strike this medal in homage to Alberto Santos-Dumont. 19th October 1901."

* "Through *heavens* hereto unsailed," instead of

"*Por mares nunca d'antes navegados*"—
"O'er *seas* hereto unsailed."

ROUNDING EIFFEL TOWER

CHAPTER XVI

A GLANCE BACKWARD AND FORWARD

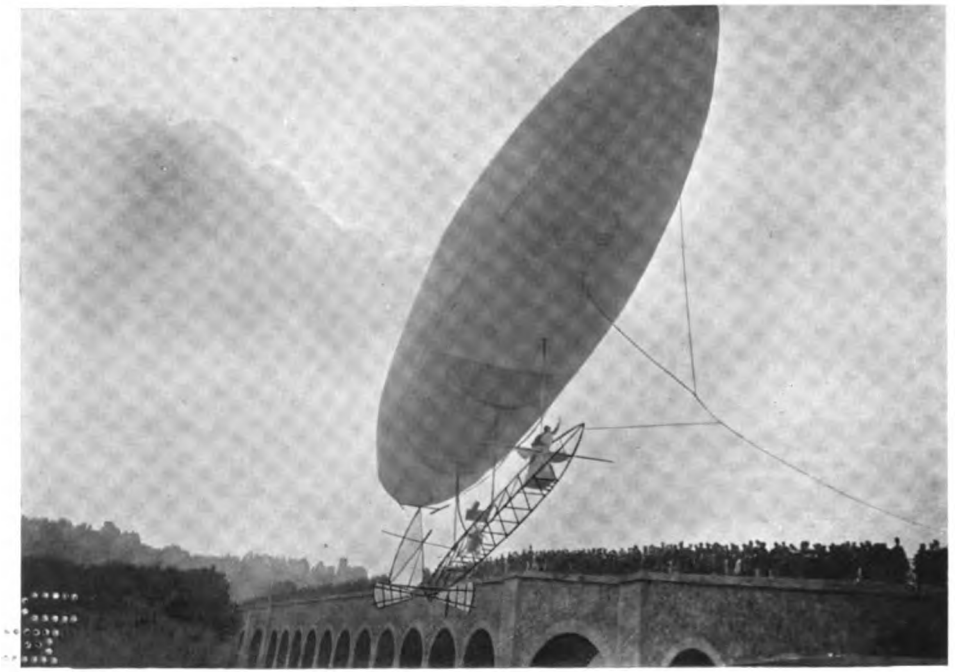
JUST as I had not gone into air-ship constructing for the sake of winning the Deutsch prize, so now I had no reason to stop experimenting after I had won it. When I built and navigated my first air-ships neither Aéro Club nor Deutsch prize were yet in existence. The two, by their rapid rise and deserved prominence, had brought the problem of aerial navigation suddenly before the public—so suddenly, indeed, that I was really not prepared to enter into such a race with a time limit. Naturally anxious to have the honour of winning such a competition, I had been forced on rapidly in new constructions at both danger and expense. Now I would take time to perfect myself systematically as an aerial navigator.

Suppose you buy a new bicycle or automobile. You will have a perfect machine to your hand without having had any of the labour, the deceptions, the false starts and recommencements, of the

inventor and constructor. Yet with all these advantages you will soon find that possession of the perfected machine does not necessarily mean that you shall go spinning over the highways with it. You may be so unpractised that you will fall off the bicycle or blow up the automobile. The machine is all right, but you must learn to run it.

To bring the modern bicycle to its perfection thousands of amateurs, inventors, engineers, and constructors laboured during more than twenty-five years, trying endless innovations, one by one rejecting the great mass of them, and, after endless failures by the way of half successes, slowly nearing to the perfect organism.

So it is to-day with the automobile. Imagine the united labours and financial sacrifices of the engineers and manufacturers that led, step by step, up to the road-racing automobiles of the Paris-Berlin competition in 1901—the year in which the only working dirigible balloon then in existence won the Deutsch prize against a time limit that was thought by many a complete bar to success. Yet of the 170 perfected automobiles registered for entry to the Paris-Berlin competition only 109 completed the first day's run, and of these only 26 finally reached Berlin.



RETURNING TO AËRO CLUB GROUNDS ABOVE AQUEDUCT

Out of 170 automobiles entered for the race only 26 reached the goal. And of these 26 arriving at Berlin how many do you imagine made the trip without serious accident? Perhaps none.

It is perfectly natural that this should be so. People think nothing of it. Such is the natural development of a great invention. But if I break down while in the air I cannot stop for repairs: I must go on, and the whole world knows it.

Looking back, therefore, on my progress since the time I doubled up above the Bagatelle grounds in 1898 I was surprised at the rapid pace at which I had allowed the notice of the world and my own ardour to push me on in what was in reality an arbitrary task. At the risk of my neck and the needless sacrifice of a great deal of money I had won the Deutsch prize. I might have arrived at the same point of progress by less forced and more reasonable stages. Throughout I had been inventor, patron, manufacturer, amateur, mechanician, and air-ship captain all united! Yet any one of these qualities is thought to bring sufficient work and credit to the individual in the world of automobiles.

With all these cares I often found myself

criticised for choosing calm days for my experiments. Yet who, experimenting over Paris—as I had to do when trying for the Deutsch prize—would add to his natural risks and expenses the vexations of who knows what prosecution for knocking down the chimney-pots of a great capital on the heads of a population of pedestrians?

One by one I tried the assurance companies. None would make a rate for me against the damage I might do on a squally day. None would give me a rate on my own air-ship to insure it against destruction.

To me it was now clear that what I most needed was navigation practice pure and simple. I had been increasing the speed of my air-ships—that is to say, I had been constructing at the expense of my education as an air-ship captain.

The captain of a steamboat obtains his certificate only after years of study and experience of navigation in inferior capacities. Even the "chauffeur" on the public highway must pass his examination before the authorities will give him his papers.

In the air, where all is new, the routine navigation of a dirigible balloon, requiring for founda-

MEDAL AWARDED BY THE BRAZILIAN GOVERNMENT

tion the united experiences of the spherical balloonist and the automobile "chauffeur," makes demands upon the lone captain's coolness, ingenuity, quick reasoning, and a kind of instinct that comes with long habit.

Urged on by these considerations, my great object in the autumn of 1901 was to find a favourable place for practice in aerial navigation.

My swiftest and best air-ship—"The Santos-Dumont No. 6"—was in perfect condition. The day after winning the Deutsch prize in it my chief mechanician asked me if he should tighten it up with hydrogen. I told him yes. Then, seeking to let some more hydrogen into it, he discovered something curious. The balloon would not take any more! It had not lost a single cubic unit of hydrogen!

The actual winning of the Deutsch prize had cost only a few litres of petroleum!

Just as the Paris winter of biting winds, cold rains, and lowering skies was approaching I received an intimation that the Prince of Monaco, himself a man of science celebrated for his personal investigations, would be pleased to build a balloon house directly on the beach of La

Condamine, from which I might dart out on the Mediterranean, and so continue my aerial practice through the winter.

The situation promised to be ideal. The little bay of Monaco, sheltered from behind against the wind and cold by mountains, and from the wind and sea on either side by the heights of Monte Carlo and Monaco town, would make a well-protected manœuvre ground.

The air-ship would be always ready, filled with hydrogen gas. It could slip out of the balloon house to profit by good weather, and back again for shelter at the approach of squalls. The balloon house would be erected on the edge of the shore, and the whole Mediterranean would lie before me for guide-roping.

"No. 9." SHOWING CAPTAIN LEAVING BASKET FOR MOTOR

CHAPTER XVII

MONACO AND THE MARITIME GUIDE ROPE

WHEN I arrived at Monte Carlo, in the latter part of January 1902, the balloon house of the Prince of Monaco was already practically completed from suggestions I had given.

The new aerodrome rose on the Boulevard de la Condamine, just across the electric tramcar tracks from the sea wall. It was an immense empty shell of wood and canvas over a stout iron skeleton 55 metres (180 feet) long, 10 metres (33 feet) wide, and 15 metres (50 feet) high. It had to be solidly constructed, not to risk the fate of the all-wood aerodrome of the French Maritime Ballooning Station at Toulon, twice wrecked, and once all but carried away, like a veritable wooden balloon, by tempests.

In spite of the aerodrome's risky form and curious construction its sensational features were its doors. Tourists told each other (quite correctly) that doors so great as these had never

been before in ancient times or modern. They had been made to slide open and shut, above on wheels hanging from an iron construction that extended from the façade on each side, and below on wheels that rolled over a rail. Each door was 15 metres (50 feet) high by 5 metres (16½ feet) wide, and each weighed 4400 kilogrammes (9680 lbs.). Yet their equilibrium was so well calculated that on the day of the inauguration of the aerodrome these giant doors were rolled apart by two little boys of eight and ten years respectively, the young Princes Ruspoli, grandsons of the Duc de Dino, my host at Monte Carlo.

While the new situation attracted me by its promise of convenient and protected winter practice the prospect of doing some oversea navigation with my air-ship was even more alluring. Even to the spherical balloonist the oversea problem has great temptations, concerning which an expert of the French Navy has said:

"The balloon can render the navy immense services, *on condition that its direction can be assured.*

"Floating over the sea, it can be at once scout and offensive auxiliary of so delicate a character

IN THE BAY OF MONACO

that the general service of the navy has not yet allowed itself to pronounce on the matter. We can no longer conceal it from ourselves, however, that the hour approaches when balloons, now become military engines, will acquire, from the point of view of battle results, a great and, perhaps, decisive influence in war."

As for myself, I have never made it any secret that, to my mind, the first practical use of the air-ship will be found in war, and the far-seeing Henri Rochefort, who was in the habit of coming to the aerodrome from his hotel at La Turbie, wrote a most significant editorial in this sense after I had laid before him the speed calculations of my "No. 7," then in course of building.

"The day when it shall be established that a man can make his air-ship travel in a given direction and manœuvre it at will during the four hours which the young Santos demands to go from Monaco to Calvi," wrote Henri Rochefort, "there will remain little more for the nations to do than to throw down their arms. . . .

"I am astonished that the capital importance of this matter has not yet been grasped by all the professionals of aerostation. To mount in a balloon that one has not constructed, and which

one is not in a state to guide, constitutes the easiest of performances. A little cat has done it at the Folies-Bergère."

Now in war service overland the air-ship will, doubtless, have often to mount to considerable heights to avoid the rifle fire of the enemy, but, as the maritime auxiliary described by the expert of the French Navy, its scouting *rôle* will for the most part be performed at the end of its guide rope, comparatively close to the waves, and yet high enough to take in a wide view. Only when for easily-imagined reasons it is desired to mount high for a short time will it quit the convenient contact of its guide rope with the surface of the sea.

For these considerations—and particularly the last—I was anxious to do a great deal of guide-roping over the Mediterranean. If the maritime experiment promises so much to spherical ballooning it is doubly promising to the air-ship, which, from the nature of its construction, carries comparatively little ballast. This ballast ought not to be currently sacrificed, as it is by the spherical balloonist, for the remedying of every little vertical aberration. Its purpose is for use in great emergencies. Nor ought the aerial navigator, particu-

larly if he be alone, be forced to rectify his altitude continually by means of his propeller and shifting weights. He ought to be free to navigate his air-ship; if on pleasure bent, with ease and leisure to enjoy his flight; if on war service, with facility for his observations and hostile manœuvres. Therefore any *automatic* guarantee of vertical stability is peculiarly welcome to him.

You know already what the guide rope is. I have described it in my first experience of spherical ballooning. Overland, where there are level plains or roads or even streets, where there are not too many troublesome trees, buildings, fences, telegraph and trolley poles and wires and like irregularities, the guide rope is as great an aid to the air-ship as to the spherical balloon. Indeed, I have made it more so, for with me it is the central feature of my shifting weights (Figs. 8 and 9, page 148).

Over the uninterrupted stretches of the sea my first Monaco flight proved it to be a true *stabilisateur*. Its very slight dragging resistance through the water is out of all proportion to the considerable weight of its floating extremity. According to its greater or less immersion, therefore, it ballasts or unballasts the air-ship (Fig. 11). The balloon is

held by the weight of the guide rope down to a fixed level over the waves without danger of being drawn into contact with them. For the moment that the air-ship descends the slightest distance nearer to them that very moment it becomes relieved of just so much weight, and must naturally

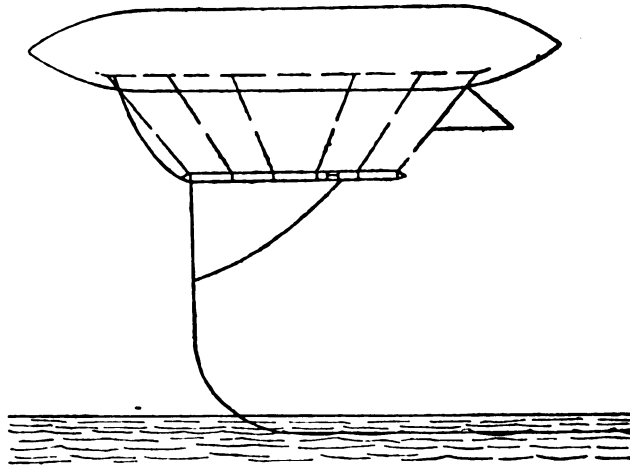


Fig. 11

rise again by that amount of momentary unballasting. In this way an incessant little tugging toward and away from the waves is produced, infinitely gentle, an automatic ballasting and unballasting of the air-ship without loss of ballast.

My first flight over the Mediterranean, which was made on the morning of 29th January 1902,

proved more than this, unfortunately. It was seen that a miscalculation had been made with respect to the site of the aerodrome itself. In the navigation of the air, where all is new, such surprises meet the experimenter at every turn. This ought to be remembered when one takes account of progress. In the Paris-Madrid automobile race of 1903 what minute precautions were not taken to secure the competitors against the perils of quick turnings and grade crossings? And yet how notably insufficient did they not turn out to be.

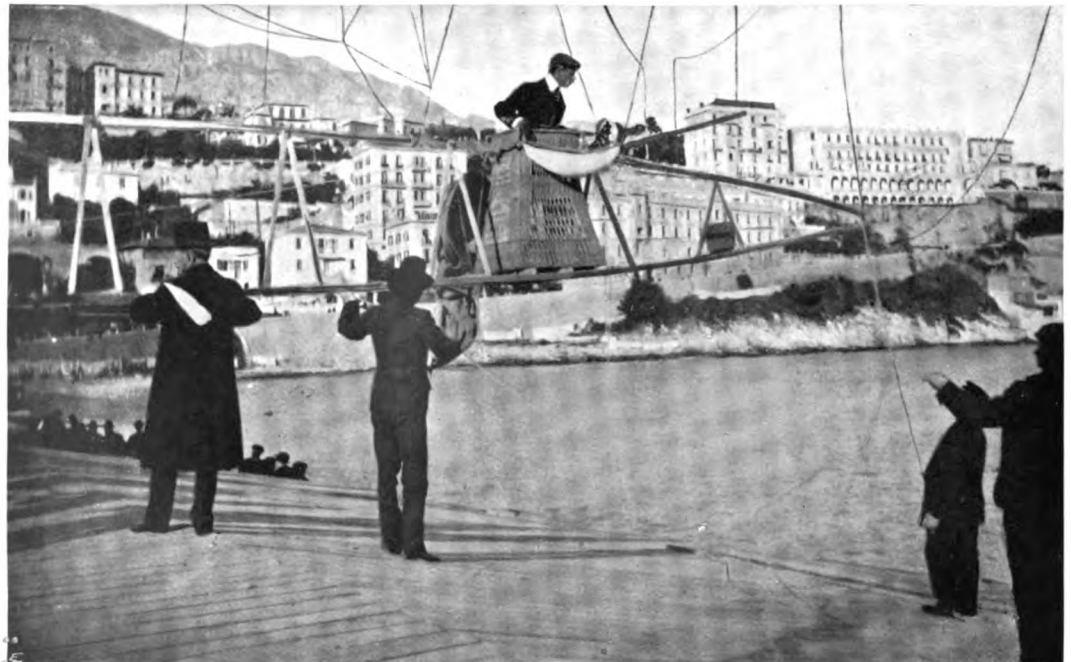
As the air-ship was being taken out from its house for its first flight on the morning of 29th January 1902 the spectators could see that nothing equivalent to the landing-stages which the air-ships of the future must have built for them existed in front of the building. The air-ship, loaded with ballast until it was a trifle heavier than the surrounding atmosphere, had to be towed, or helped, out of the aerodrome and across the Boulevard de la Condamine before it could be launched into the air over the sea wall.

Now that sea wall proved to be a dangerous obstruction. From the side walk it was only waist high, but on the other side of it the surf

rolled over pebbles from four to five metres below.

The air-ship had to be lifted over the sea wall more than waist high; also, not to risk damaging the arms of its propeller, and when half over, there was no one to sustain it from the other side. Its stem pointed obliquely downward, while its stern threatened to grind on the wall. Scuffling among the pebbles below, on the sea side, half-a-dozen workmen held their arms high toward the descending keel as it was let down and pushed on toward them by the workmen in charge of it on the boulevard in front of the wall, and they were at last able to catch and right it only in time to prevent me from being precipitated from the basket.

For this reason my return to the aerodrome after this first flight became the occasion of a real triumph, for the crowd promptly took cognisance of the perils of the situation and foresaw difficulties for me when I should attempt to reenter the balloon house. As there was no wind, however, and as I steered boldly, I was able to make a sensational entry without damage — and without aid. Straight as a dart the air-ship sped to the balloon house. The police of the prince



FROM THE BALLOON HOUSE OF LA CONDAMINE AT MONACO, FEB. 12, 1902

had with difficulty cleared the boulevard between the sea wall and the wide-open doors. Assistants and supernumeraries leaned over the wall with outstretched arms waiting for me; below on the beach were others, but this time I did not need them. I slowed the speed of the propeller as I came to them. Just as I was half way over the sea wall, well above them all, I stopped the motor. Carried onward by the dying momentum, the air-ship glided over their heads on toward the open door. They had grasped my guide rope to draw me down, but as I had been coming diagonally there was no need of it. Now they walked beside the air-ship into the balloon house, as its trainer or the stable-boys grasp the bridle of their racehorse after the course and lead him back in honour to the stable with his jockey in the saddle.

It was admitted, nevertheless, that I ought not to be obliged to steer so closely on returning from my flights—to enter the aerodrome as a needle is threaded by a steady hand—because a side gust of wind might catch me at the critical moment and dash me against a tree or lamp-post, or telegraph or telephone pole, not to speak of the sharp-cornered buildings on either side of the

aerodrome. When I went out again for a short spin that same afternoon of 29th January 1902 the obstruction of the sea wall made itself only too evident. The prince offered to tear down the wall.

"I will not ask you to do so much," I said. "It will be enough to build a landing-stage on the sea side of the wall at the level of the boulevard."

This was done after twelve days of work, interrupted by persistent rain, and the air-ship, when it issued for its third flight, 10th February 1902, had simply to be lifted a few feet by men on each side of the wall. They drew it gently on until its whole length floated in equilibrium over the new platform that extended so far out into the surf that its farthermost piles were always in six feet of water.

Standing on this platform they steadied the air-ship while its motor was being started, while I let out the overplus of water ballast and shifted my guide rope so as to point for an oblique drive upward. The motor began spitting and rumbling. The propeller began turning.

"Let go all!" I cried, for the third time at Monaco.

Lightly the air-ship slid along its oblique course, onward and upward. Then as the propeller gathered force a mighty push sent me flying over the bay. I shifted forward the guide rope again to make a level course. And out to sea the air-ship darted, its scarlet pennant fluttering symbolic letters as upon a streak of flame. They were the initial letters of the first line of Camoëns' "Lusiad," the epic poet of my race:

Por mares nunca d'antes navegados!
(O'er seas hereto unsailed.)

CHAPTER XVIII

FLIGHTS IN MEDITERRANEAN WINDS

In my two previous experiments I had kept fairly within the wind-protected limits of the bay of Monaco, whose broad expanse afforded ample room both for guide-roping and practice in steering. Furthermore, a hundred friends and thousands of friendly spectators stood around it from the terraces of Monte Carlo to the shore of La Condamine and up the other side to the heights of Old Monaco. As I circled round and round the bay, mounted obliquely and swooped down, fetched a straight course, and then stopped abruptly to turn and begin again, their applause came up to me agreeably. Now, on my third flight, I steered for the open sea.

Out into the open Mediterranean I sped. The guide rope held me at a steady altitude of about 50 metres above the waves, as if in some mysterious way its lower end were attached to them.

In this way, automatically secure of my altitude, I found the work of aerial navigation become wonderfully easy. There was no ballast to throw out, no gas to let out, no shifting of the weights except when I expressly desired to mount or descend. So with my hand upon the rudder and my eye fixed on the far-off point of Cap Martin I gave myself up to the pleasure of this voyaging above the waves.

Here in these azure solitudes there were no chimney-pots of Paris, no cruel, threatening roof-corners, no tree-tops of the Bois de Boulogne. My propeller was showing its power, and I was free to let it go. I had only to hold my course straight in the teeth of the breeze and watch the far-off Mediterranean shore flit past me.

I had plenty of leisure to look about. Presently I met two sailing yachts scudding towards me down the coast. I noticed that their sails were full-bellied. As I flew on over them, and they beneath me, I heard a faint cheer, and a graceful female figure on the foremost yacht waved a red foulard. As I turned to answer the politeness I perceived with some astonishment that we were far apart already.

I was now well up the coast, about half-way

to Cap Martin. Above was the limitless blue void. Below was the solitude of white-capped waves. From the appearance of sailing boats here and there I could tell that the wind was increasing to a squall, and I would have to turn in it before I could fly back upon it in my homeward trip.

Porting my helm I held the rudder tight. The air-ship swung round like a boat; then as the wind sent me flying down the coast my only work was to maintain the steady course. In scarcely more time than it takes to write it I was opposite the bay of Monaco again.

With a sharp turn of the rudder I entered the protected harbour, and amid a thousand cheers stopped the propeller, pulled in the forward shifting weight, and let the dying impetus of the air-ship carry it diagonally down to the landing-stage. This time there was no trouble. On the broad landing-stage stood my own men, assisted by those put at my disposition by the prince. The air-ship was grasped as it came gliding slowly to them, and, without actually coming to a stop, it was "led" over the sea wall across the Boulevard de la Condamine and into the aerodrome. The trip had lasted less than an hour,

and I had been within a few hundred metres (yards) of Cap Martin.

Here was an obvious trip, first against and then with a stiff wind, and the curious may render themselves an account of the fact by glancing at the two photographs marked "Wind A" and "Wind B." As they happened to be taken by a Monte Carlo professional intent simply on getting good photographs they are impartial.

"Wind A" shows me leaving the bay of Monaco against a wind that is blowing back the smoke of the two steamers seen on the horizon.

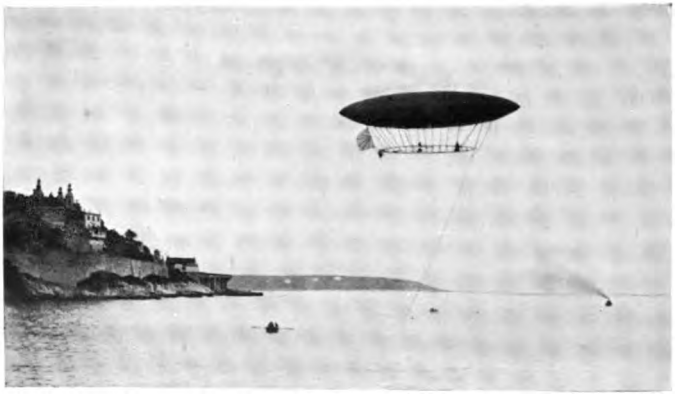
"Wind B" was taken up the coast just before I met the two little sailing yachts which are obviously scudding toward me.

The loneliness in which I found myself in the middle of this first extended flight up the Mediterranean shore was not part of the programme. During the manufacture of the hydrogen gas and the filling of the balloon I had received the visits of a great many prominent people, several of whom signified their ability and readiness to lend valuable aid to these experiments. From Beaulieu, where his steam-yacht, *Lysistrata*, was at anchor, came Mr James

Gordon Bennett, and Mr Eugene Higgins had already brought the *Varuna* up from Nice on more than one occasion. The beautiful little steam-yacht of M. Eiffel also held itself in readiness.

It had been the intention of these owners, as it had been that of the prince with his *Princesse Alice*, to follow the air-ship in its flights over the Mediterranean, so as to be on the spot in case of accident. This first flight, however, had been taken on impulse before any programme for the yachts had been arranged, and my next long flight, as will be seen, demonstrated that this kind of protection must not be counted on overmuch by air-ship captains.

It was on the 12th of February 1902. One steam chaloupe and two petroleum launches, all three of them swift goers, together with three well-manned row-boats, had been stationed at intervals down the coast to pick me up in case of accident. The steam *chaloupe* of the Prince of Monaco, carrying His Highness, the Governor-General, and the captain of the *Princesse Alice*, had already started on the course ahead of time. The 40 horse-power Mors automobile of Mr Clarence Grey Dinsmore and the 30 horse-power Panhard



"WIND A"

"WIND B"

of M. Isidore Kahenstein were prepared to follow along the lower coast road.

Immediately on leaving the bay of Monaco I met the wind head on as I steered my course straight down the coast in the direction of the Italian frontier. Putting on all speed I held the rudder firm and let myself go. I could see the ragged outlines of the coast flit past me on the left. Along the winding road the two racing automobiles kept abreast with me, being driven at high speed.

"It was all we could do to follow the air-ship along the curves of the coast road," said one of Mr Dinsmore's passengers to the reporter of a Paris journal, "so rapid was its flight. In less than five minutes it had arrived opposite the Villa Camille Blanc, which is about a kilometre (¾ of a mile) distant from Cap Martin as the crow flies.

"At this moment the air-ship was absolutely alone. Between it and Cap Martin I saw a single row-boat, while far behind was visible the smoke from the prince's *chaloupe*. It was really no commonplace sight to see the air-ship thus hovering isolated over the immense sea."

The wind instead of subsiding had been increasing. Here and there around the horizon I

could see the bent white sails of yachts driven before it. The situation was new to me, so I made an abrupt turn and started back on the home stretch.

Now again the wind was with me, stronger than it had been on the preceding flight down the coast. Yet it was easy steering, and I remarked with pleasure that going thus with the wind the pitching or *tangage* of the air-ship was much less. Though going fast with my propeller, and aided by the wind behind me, I felt no more motion, indeed even less, than before.

For the rest, how different were my sensations from those of the spherical balloonist! It is true that he sees the earth flying backward beneath him at tremendous speed. But he knows that he is powerless. The great sphere of gas above him is the plaything of the air current, and he cannot change his direction by a hair's-breadth. In my air-ship I could see myself flying over the sea, but I had my hands on a helm that made me master of my direction in this splendid course. Once or twice, merely to give myself an account of it, I shoved the helm around a short arc. Obedient, the air-ship's stem swung to the other side, and I found myself speeding in a new diagonal course.

But these manœuvres only occupied a few instants each, and each time I swung myself back on a straight line to the entrance to the bay of Monaco, for I was flying homeward like an eagle, and must keep my course.

To those watching my return, from the terraces of Monte Carlo and Monaco town, as they told me afterwards, the air-ship increased in size at every instant, like a veritable eagle bearing down upon them. As the wind was coming toward them they could hear the low, crackling rumble of my motor a long distance off. Faintly, now, their own shouts of encouragement came to me. Almost instantly the shouts grew loud. Around the bay a thousand handkerchiefs were fluttering. I gave a sharp turn to the helm, and the air-ship leaped into the bay amid the cheering and the waving just as great raindrops were beginning to fall.*

I had first slowed and then stopped the motor. As the air-ship now gently approached the landing-stage, borne on by its dying momentum, I

* "Half-an-hour after the aeronaut's return the wind became violent, a heavy storm followed, and the sea became very rough." (Paris edition, *New York Herald*, 13th February 1902.)

gave the usual signal for those in the boats to seize my guide rope. The steam *chaloupe* of the prince, which had turned back midway between Monte Carlo and Cap Martin after I had overtaken and passed it on my out trip, had by this time reached the bay. The prince, who was still on board, desired to catch the guide rope; and those with him, having no experience of its weight and the force with which the air-ship drags it through the water, did not seek to dissuade him. Instead of catching the heavy floating cordage as the darting *chaloupe* passed it His Highness managed to get struck by it on the right arm, an accident which knocked him fairly to the bottom of the little vessel and produced severe contusions.

A second attempt to catch the guide rope was more successful, and the air-ship was easily drawn to the sea wall, over it, and into its house. Like everything in this new navigation, the particular manœuvre was new. I was still going faster than I appeared to be, and such attempts to catch and stop an air-ship even on its dying momentum are apt to upset someone. The only way not to get too abrupt a shock is to run with the machine and slow it down gently.

CHAPTER XIX

SPEED

WHAT speed my "No. 6" made on those Mediterranean flights was not published at the time because I had not sought to calculate it closely. Fresh from the troubling time limit of the Deutsch prize competition I amused myself frankly with my air-ship, making observations of great value to myself, but not seeking to prove anything to anyone.

The speed problem is, doubtless, the first of all air-ship problems. Speed must always be the final test between rival air-ships, and until high speed shall be arrived at certain other problems of aerial navigation must remain in part unsolved. For example, take that of the air-ship's pitching (*tangage*). I think it quite likely that a critical point in speed will be found, beyond which, on each side, the pitching will be practically *nil*. When going slowly or at moderate speed I have experienced no pitching, which in an air-ship

like my "No. 6" seems always to commence at 25 to 30 kilometres (15 to 18 miles) per hour through the air. Now, probably, when one passes this speed considerably—say at the rate of 50 kilometres (30 miles) per hour—all *tangage* or pitching will be found to cease again, as I myself experienced when flying homeward on the wind in the voyage last described.

Speed must always be the final test between rival air-ships, because, in itself, speed sums up all other air-ship qualities, including "stability." At Monaco, however, I had no rivals to compete with. Furthermore, my prime study and amusement there was the beautiful working of the maritime guide rope; and this guide rope, dragging through the water, must of necessity retard whatever speed I made. There could be no help for it. Such was the price I must pay for automatic equilibrium and vertical stability—in a word, easy navigation—so long as I remained the sole and solitary navigator of the air-ship.

Nor is it an easy task to calculate an air-ship's speed. On those flights up and down the Mediterranean coast the speed of my return to Monaco, wonderfully aided by the wind, could bear no relation to the speed out, retarded by the wind,

and there was nothing to show that the force of the wind going and coming was constant. It is true that on those flights one of the difficulties standing in the way of such speed calculations—the "shoot the chutes" (*montagnes Russes*) of ever-varying altitude—was done away with by the operation of the maritime guide rope; but, on the other hand, as has been said, the dragging of the guide rope's weight through the water acted as a very effectual brake. As the speed of the air-ship is increased this brake-like action of the guide rope (like that of the resistance of the atmosphere itself) grows, not in proportion to the speed, but in proportion to the square of it.

On those flights along the Mediterranean coast the easy navigation afforded me by the maritime guide rope was purchased, as nearly as I could calculate, by the sacrifice of about 7 or 8 kilometres (4 or 5 miles) per hour of speed; but with or without maritime guide rope the speed calculation has its own almost insurmountable difficulties.

From Monte Carlo to Cap Martin at 10 o'clock of a given morning may be quite a different trip from Monte Carlo to Cap Martin at noon of the same day; while from Cap Martin to Monte

Carlo, except in perfect calm, must always be a still different proposition. Nor can any accurate calculations be based on the markings of the anemometer, an instrument which I, nevertheless, carried. Out of simple curiosity I made note of its readings on several occasions during my trip of 12th February 1902. It seemed to be marking between 32 and 37 kilometres (20 and 23 miles) per hour; but the wind, complicated by side gusts, acting at the same time on the air-ship and the wings of the anemometer windmill—*i.e.* on two moving systems whose inertia cannot possibly be compared—would alone be sufficient to falsify the result.

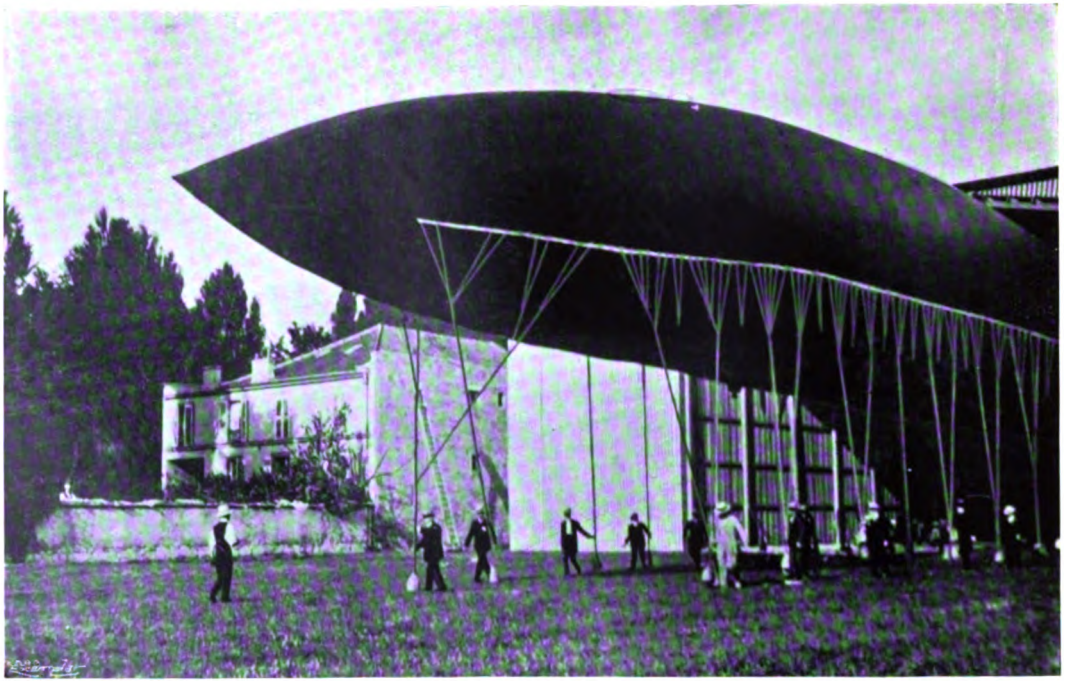
When, therefore, I state that, according to my best judgment, the average of my speed through the air on those flights was between 30 and 35 kilometres (18 and 22 miles) per hour, it will be understood that it refers to speed through the air whether the air be still or moving and to speed retarded by the dragging of the maritime guide rope. Putting this adverse influence at the moderate figure of 7 kilometres (4½ miles) per hour my speed through the still or moving air would be between 37 and 42 kilometres (22 and 27 miles) per hour.

Rather than spend time over illusory calculations on paper I have always preferred to go on materially improving my air-ships. Later, when they come in competition with the rivals which no one awaits more ardently than myself, all speed calculations made on paper and all disputes based on them must of necessity yield to the one sublime test of air-ship racing.

Where speed calculations have their real importance is in affording necessary *data* for the construction of new and more powerful air-ships. Thus the balloon of my racing "No. 7," whose motive power depends on two propellers each 5 metres (16½ feet) in diameter, and worked by a 60 horse-power motor with a water cooler, has its envelope made of two layers of the strongest French silk, four times varnished, capable of standing, under dynamometric test, a traction of 8000 kilogrammes (6600 pounds) for the linear metre (3·3 feet). I will now try to explain why the balloon envelope must be made so very much stronger as the speed of the air-ship is designed to be increased; and in so doing I shall have to reveal the unique and paradoxical danger that besets high-speed dirigibles, threatening them, not with beating their heads in against the outer

atmosphere, but with blowing their tails out behind them.

Although the interior pressure in the balloons of my air-ships is very considerable, as balloons go, the spherical balloon, having a hole in its bottom, is under no such pressure: it is so little in comparison with the general pressure of the atmosphere, that we measure it, not by "atmospheres," but by centimetres or millimetres of water pressure —*i.e.* the pressure that will send a column of water up that distance in a tube. One "atmosphere" means one kilogramme of pressure to the square centimetre (15 lbs. to the square inch), and it is equivalent to about 10 metres of water pressure, or, more conveniently, 1000 centimetres of "water." Now, supposing the interior pressure in my slower "No. 6" to have been close up to 8 centimetres of water (it required that pressure to open its gas valves), it would have been equivalent to $\frac{1}{125}$ of an atmosphere; and as one atmosphere is equivalent to a pressure of 1000 grammes (1 kilogramme) on one square centimetre the interior pressure of my "No. 6" would have been $\frac{1}{125}$ of 1000 grammes, or 8 grammes. Therefore on one square metre (10,000 square centimetres) of the stem head of the balloon of



"SANTOS-DUMONT No. 7"

my "No. 6" the interior pressure would have been 10,000 multiplied by 8, or 80,000 grammes *i.e.*—80 kilogrammes (66 lbs.).

How is this interior pressure maintained without being exceeded? Were the great exterior balloon filled with hydrogen and then sealed up with wax at each of its valves, the sun's heat might expand the hydrogen, make it exceed this pressure, and burst the balloon; or should the sealed balloon rise high, the decreasing pressure of the outer atmosphere might let its hydrogen expand, with the same result. The gas valves of the great balloon, therefore, must *not* be sealed; and, furthermore, they must always be very carefully made, so that they will open of their own accord at the required and calculated pressure.

This pressure (of 8 centimetres in the "No. 6"), it ought to be noted, is attained by the heating of the sun or by a rise in altitude only when the balloon is completely filled with gas: what may be called its working pressure — about one-fifth lower—is maintained by the rotary air pump. Worked continually by the motor, it pumps air continually into the smaller interior balloon. As much of this air as is needed to preserve the

outer balloon's rigidity remains inside the little interior balloon, but all the rest pushes its way out into the atmosphere again through its air valve, which opens at a little less pressure than do the gas valves.

Let us now return to the balloon of my "No. 6." The *interior* pressure on each square metre of its stem head being continuously about 30 kilogrammes the silk material composing it must be normally strong enough to stand it; nevertheless, it will be easy to see how it becomes more and more relieved of that interior pressure as the air-ship gets in motion and increases speed. Its striking against the atmosphere makes a counter pressure *against the outside* of the stem head. Up to 30 kilogrammes to the square metre, therefore, all increase in the air-ship's speed tends to reduce strain, so that the faster the air-ship goes the less will it be liable to burst out its head!

How fast may the balloon be carried on by motor and propeller before its head stem strikes the atmosphere hard enough to more than neutralise the interior pressure? This, too, is a matter of calculation; but, to spare the reader, I will content myself with pointing out that my flights over the Mediterranean proved that the balloon

of my "No. 6" could safely stand a speed of 36 to 42 kilometres (22 to 27 miles) per hour without giving the slightest hint of strain. Had I wanted an air-ship of the proportions of the "No. 6" to go twice as fast under the same conditions its balloon must have been strong enough to stand four times its interior pressure of 8 centimetres of "water," because the resistance of the atmosphere grows not in proportion to the speed but in proportion to the square of the speed.

The balloon of my "No. 7" is not, of course, built in the precise proportions of that of my "No. 6," but I may mention that it has been tested to resist an interior pressure of much more than 12 centimetres of "water"; in fact, its gas valves open at that pressure only. This means just four times the interior pressure of my "No. 6." Comparing the two balloons in a general way, it is obvious, therefore, that with no risk from outside pressure, and with positive relief from interior pressure on its stem or head, the balloon of my "No. 7" may be driven twice as fast as my easy-going Mediterranean pace of 42 kilometres (25 miles) per hour, or 80 kilometres (50 miles).

This brings us to the unique and paradoxical weakness of the fast-going dirigible. Up to the

point where the exterior shall equal the interior pressure we have seen how every increase of speed actually guarantees safety to the stem of the balloon. Unhappily, it does not remain true of the balloon's stern head. On it the interior pressure is also continuous, but speed cannot relieve it. On the contrary, the *suction* of the atmosphere behind the balloon, as it speeds on, increases also almost in the same proportion as the pressure caused by driv-

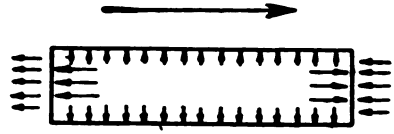


Fig. 12

ing the balloon against the atmosphere. And this suction, instead of operating to neutralise the interior pressure on the balloon's stern head, *increases* the strain just that much, the pull being added to the push. Paradoxical as it may seem, therefore, the danger of the swift dirigible is to blow its tail out rather than its head in. (See Fig. 12.)

How is this danger to be met? Obviously by strengthening the stern part of the balloon envelope. We have seen that when the speed of my "No. 7" shall be just great enough to completely neutralise the interior pressure on its stem

head the strain on its stern head will be practically doubled. For this reason I have doubled the balloon material at this point.

I have reason to be careful of the balloon of my "No. 7." In it the speed problem will be attacked definitely. It has two propellers, each 5 metres (16½ feet) in diameter. One will push, as usual, from the stern, while the other will pull from the stem, as in my "No. 4." Its 60 horse-power Clement motor will, if my expectations are fulfilled, give it a speed of between 70 and 80 kilometres (40 and 50 miles) per hour. In a word, the speed of my "No. 7" will bring us very close to practical, everyday aerial navigation, for as we seldom have a wind blowing as much even as 50 kilometres (30 miles) per hour such an air-ship will surely be able to go out daily during more than ten months in the twelve.

CHAPTER XX

AN ACCIDENT AND ITS LESSONS

At half-past two o'clock on the afternoon of the 14th of February 1902 the staunch air-ship which won the Deutsch prize left the aerodrome of La Condamine on what was destined to be its last voyage.

Immediately on quitting the aerodrome it began behaving badly, dipping heavily. It had left the balloon house imperfectly inflated, hence it lacked ascensional force. To keep my proper altitude I increased its diagonal pointing and kept the propeller pushing it on upward. The dipping, of course, was due to the counter effort of gravity.

In the shaded atmosphere of the aerodrome the air had been comparatively cool. The balloon was now out in the hot, open sunlight. As a consequence, the hydrogen nearest to the silk cover rarefied rapidly. As the balloon had left the aerodrome imperfectly inflated the rarefied hydrogen was able to rush to the highest possible

point—the up-pointing stem. This exaggerated the inclination which I had made purposely. The balloon pointed higher and higher. Indeed, for a time, it seemed almost to be pointing perpendicularly.

Before I had time to correct this "rearing up" of my aerial steed many of the diagonal wires had begun to give way, as the slanting pressure on them was unusual, and others, including those of the rudder, caught in the propeller.

Should I leave the propeller to grind on the rigging the balloon envelope would be torn the next moment, the gas would leave the balloon in a mass, and I would be precipitated into the waves with violence.

I stopped the motor. I was now in the position of an ordinary spherical balloonist—at the mercy of the winds. These were taking me in shore, where I would be presently cast upon the telegraph wires, trees, and house corners of Monte Carlo.

There was but one thing to do.

Pulling on the manœuvre valve I let out a sufficient quantity of hydrogen and came slowly down to the surface of the water, in which the air-ship sank.

Balloon, keel, and motor were successfully fished up the next day and shipped off to Paris for repairs. Thus abruptly ended my maritime experiments; but thus also I learned that, while a properly inflated balloon, furnished with the proper valves, has nothing to fear from gas displacement, it is best to be on the safe side and guard oneself against the possibility of such displacement, when by some neglect or other the balloon is allowed to go out imperfectly inflated.

For this reason, in all my succeeding air-ships, the balloon is divided into many compartments by vertical silk partitions, not varnished. The partitions remaining unvarnished, the hydrogen gas can slowly pass through their meshes from one compartment to another to ensure an equal pressure throughout. But as they are, nevertheless, partitions, they are always ready to guard against any precipitous rushing of gas toward either extremity of the balloon.

Indeed, the experimenter with dirigible balloons must be continually on his guard against little errors and neglects of his aids. I have four men who have now been with me four years. They are in their way experts, and I have every confidence in them. Yet this thing happened: the

air-ship was allowed to leave the aerodrome imperfectly inflated. Imagine, then, what might be the danger of an experimenter with a set of inexperienced subordinates.

In spite of their great simplicity my air-ships require constant surveillance on a few capital heads:

Is the balloon properly filled?

Is there any possibility of a leak?

Is the rigging in condition?

Is the motor in condition?

Do the cords commanding rudder, motor, water ballast, and the shifting guide rope work freely?

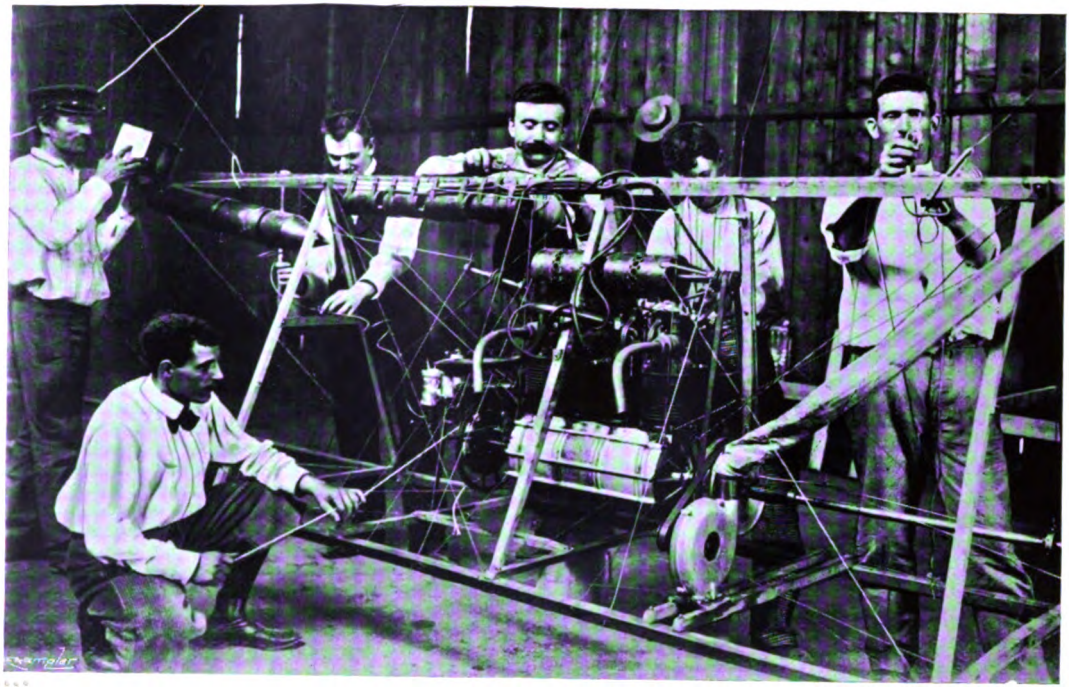
Is the ballast properly weighed?

Looked on as a mere machine the air-ship requires no more care than an automobile, but, from the point of view of consequences, the need of faithful and intelligent surveillance is simply imperious. This very day all the highways of France are dotted with a thousand automobiles *en panne*, with their enthusiastic drivers crawling underneath them in the dust, oil-can and wrench in hand, repairing momentary accidents. They think no less of their automobile for this reason. Yet let the air-ship have the same trifling accident and all the world is likely to hear of the fact.

In the first years of my experiments I insisted on doing everything for myself. I "groomed" my balloons and motors with my own hands. My present aids understand my present air-ships, and nine times out of ten they hand them over to me in good condition for the voyage. Yet were I to begin experiments with a new type I should have to train them all anew, and during that time I should have to care for the air-ships with my own hands again.

On this occasion the air-ship left the aerodrome imperfectly weighed and inflated, not so much by the neglect of my men as by reason of the imperfect situation of the aerodrome. In spite of the care that had been given to designing and constructing it, from the very nature of its situation there was no space outside in which to send up the air-ship and ascertain if its ballast were properly distributed. Could this have been done the imperfect inflation of the balloon would have been perceived in time.

Looking back over all my varied experiences I reflect with astonishment that one of my greatest dangers passed unperceived, even by myself, at the end of my most successful flight over the Mediterranean.



"MY PRESENT AIDS UNDERSTAND MY PRESENT AIRSHIPS"
MOTOR OF "No. 6"

It was at the time the prince attempted to grasp my guide rope and was knocked into the bottom of his steam *chaloupe*. I had entered the bay after flying homeward up the coast, and they were towing me toward the aerodrome. The airship had descended very close to the surface of the water, and they were pulling it still lower by means of the guide rope, until it was not many feet above the smoke-stack of the steam *chaloupe* —and that smoke-stack was belching red-hot sparks.

Any one of those red-hot sparks might have, ascending, burned a hole in my balloon, set fire to the hydrogen, and blown balloon and myself to atoms.

CHAPTER XXI

THE FIRST OF THE WORLD'S AIR-SHIP STATIONS

AIR-SHIP experimenters labour under one peculiar disadvantage, quite apart from the proper difficulties of the problem. It is due to the utter newness of travel in a third dimension, and consists in the slowness with which our minds realise the necessity of providing for the diagonal mountings and descents of the air-ships starting from and returning to the ground.

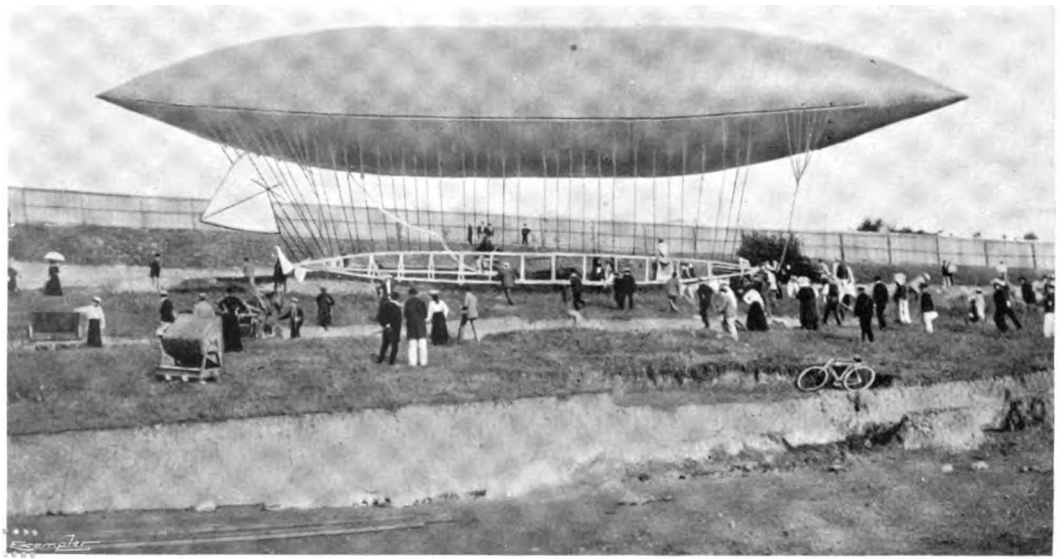
When the Aéro Club of Paris laid out its grounds at St Cloud it was with the sole idea of facilitating the vertical mounting of spherical balloons. Indeed, no provisions were made even for the landing of spherical balloons, because their captains never hoped to bring them back to the St Cloud balloon park otherwise than by rail, packed in their boxes. The spherical balloon lands where the wind takes it.

When I built my first air-ship house in the Club's grounds at St Cloud I dare say that the

then novel advantages of possessing my own gas plant, workshop, and a shelter in which the inflated dirigibles could be housed indefinitely withheld my attention from this other almost vital problem of surroundings. It was already a great progress for me not to be obliged to empty the balloon and waste its hydrogen at the end of each trip. Thus I was content to build simply an air-ship house with great sliding doors without even taking precautions to guarantee a flat, open space in front, and, less still, on either side of it. When, little by little, trenches something like a metre (yard) deep—vague foundation outlines for constructions that were never finished—began appearing here and there to the right of my open doors and on beyond I realised that my aids might risk falling into them in running to catch my guide rope when I should be returning from a trip. And when the gigantic skeleton of M. Henry Deutsch's air-ship house, designed to shelter the air-ship he built on the lines of my "No. 6," and called "La Ville de Paris," rose directly in front of my sliding doors, scarcely two air-ships' lengths distant from them, it dawned on me at last that here was something of a peril, and more than a simple inconvenience due to natural crowding in a club's

grounds. In spite of the new peril the Deutsch prize was won. Returning from the Eiffel Tower I passed high above the skeleton. I may say here, however, that the foundation trenches innocently caused the painful controversy about my time, to which I have made a brief allusion in the chapter. Seeing that they might easily break their legs by stumbling into those foundation trenches I had positively forbidden my men to run across that space to catch my guide rope with their eyes and arms up in the air. Not dreaming that such a point could be raised, my men obeyed the injunction. Observing that I was quite master of my rudder, motor, and propeller, able to turn and return to the spot where the judges stood, they let me pass on over their heads without seeking to catch and run along with the guide rope, a thing they might have done easily—at the risk of their legs.

Again, at Monaco, after a well-planned air-ship house had been erected in what seemed an ideal spot, we have seen what dangers were, nevertheless, threatened by the sea wall, the Boulevard de la Condamine with its poles, wires, and traffic, and the final disaster, due entirely to the absence of a weighing ground beside the aerodrome. These



"SANTOS-DUMONT No. 5"
SHOWING HOW AËRO CLUB GROUNDS WERE CUT UP

are dangers and inconveniences against which we come in time to be on our guard by actual and often dire experience.

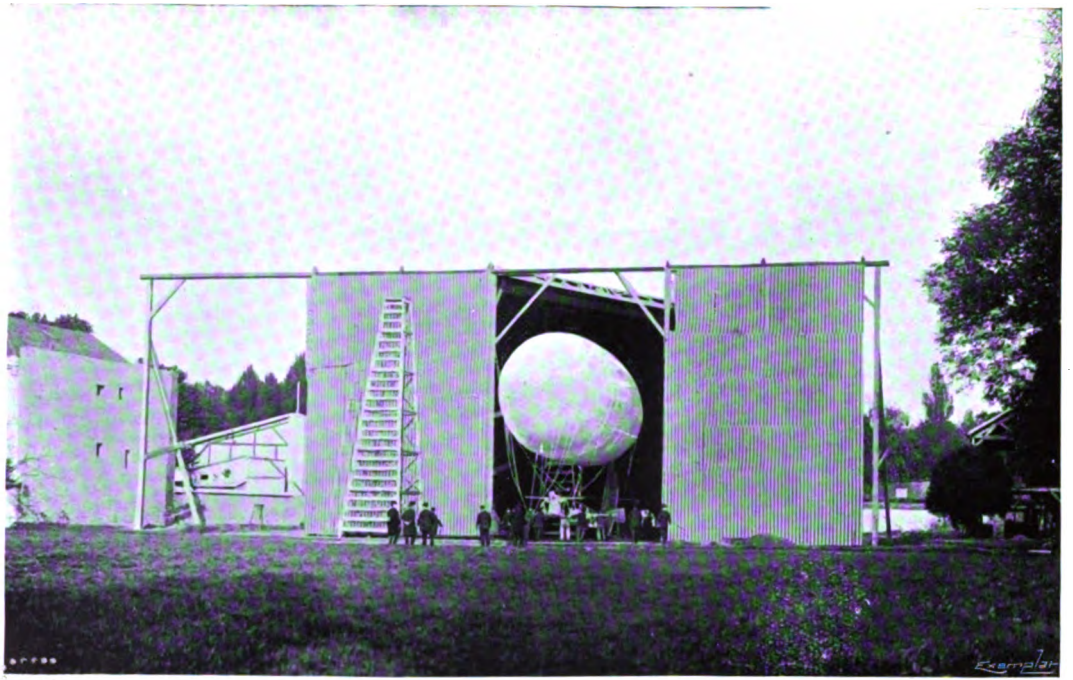
During the spring and summer of 1902 I took trips to England and the United States, of which I shall have a word to say later. Returning from those trips to Paris I at once set about selecting the site of an aerodrome that should be all my own and in which the experience gained at such cost should be taken advantage of. This time I resolved my air-ship house should have an ample space around it. And, succeeding in a way, I realised—if I may say it—the first of the air-ship stations of the future.

After long search I came on a fair-sized lot of vacant ground surrounded by a high stone wall, inside the police jurisdiction of the Bois de Boulogne, but private property, situated on the Rue de Longchamps, in Neuilly St James. First, I had to come to an understanding with its owner; then I had to come to an understanding with the Bois authorities, who took time to give a building permit to such an unusual construction as a house from which air-ships would go and come.

The Rue de Longchamps is a narrow suburban street, little built on at this end, that gives on

the Bagatelle Gate to the Bois de Boulogne, beside the training ground of the same name. To go and come in my air-ships from this side is, however, inconvenient because of the walls of the various properties, the trees that line the Bois so thickly, and the great park gates. To the right and left of my little property are other buildings. Behind me, across the Boulevard de la Seine, is the river itself, with the Ile de Puteaux in it. It is from this side that I must go and come in my air-ships. Mounting diagonally in the air from my own open grounds I pass over my wall, the Boulevard de la Seine, and turn when well above the river. Regularly I turn to the left and make my way, in a great arc, to the Bois by way of the training ground, itself a fairly open space.

There it stands in its grounds, the first of the air-ship stations of the future, capable of housing seven air-ships all inflated and prepared to navigate at an instant's notice! But in spite of all the needs that I attempted to provide for in it what a small and hampered place it is compared with the great, highly-organised stations which the future must produce for itself, with their high-placed and spacious landing-stages, to which air-



FIRST OF THE WORLD'S AIRSHIP STATIONS (NEUILLY ST JAMES)

ships will descend with complete safety and convenience, like great birds that seek nests on flat rocks! Such stations may have little car tracks running out from their interior to the wide landing-spaces. The cars that run over them will pull the air-ships in and out by their guide ropes, without loss of time or the aid of a dozen or more men. Their observation towers will serve for judges' timing stations in aerial races; fitted with wireless telegraph apparatus they may be able to communicate with distant goals and, perhaps, even with the air-ships in motion. Attached to their air-ship stations there will be gas-generating plants. There may be a case-mated workshop for the testing of motors. There will certainly be sleeping-rooms for experimenters who desire to make an early start and profit by the calm of the dawn. It is quite probable that there will also be balloon envelope workshops for repairs and changes, a carpenter shop, and a machine shop, with intelligent and experienced workmen ready and able to seize an idea and execute it.

Meanwhile my air-ship station of the present is said to resemble a great square tent, striped red and white, set in the midst of a vacant lot sur-

rounded by a high stone wall. Its tent-like appearance is due to the fact that, being in a hurry to utilise it, I saw no reason to construct its walls or roof of wood. The framework consists of long rows of parallel wooden pillars. Across their tops is stretched a canvas roof, and the four sides are made of the same striped canvas. This makes a construction stronger than it at first appears, the outside tent stuff weighing some 2600 kilogrammes (5720 lbs.), and being sustained between the pillars by metallic cordage.

Inside, the central stalls are 9½ metres (31 feet) wide, 50 metres (165 feet) long, and 13½ metres (44½ feet) high, affording room for the largest dirigibles without permitting them to come into contact with each other. The great sliding doors are but a repetition of those of Monaco.

When in the spring of 1908 I found my air-ship station completed I had three new air-ships ready to house in it. They were:

My "No. 7." This I call my racing air-ship. It is designed and reserved for important competitions, the mere cost of filling it with hydrogen being more than 3000 francs (£120). It is true that, once filled, it may be kept inflated for a month at the expense of 50 francs (£2) per day

"No. 7"

for hydrogen to replace what is lost by the daily play of condensation and dilatation. Having a gas capacity of 1257 cubic metres (nearly 45,000 cubic feet) it possesses twice the lifting power of my "No. 6," in which the Deutsch prize was won; and such is the necessary weight of its 60 horse-power, water-cooled, four-cylinder motor and its proportionally strong machinery that I shall probably take up no more ballast in it than I took up in the "No. 6." Comparing their sizes and lifting powers, it would make five of

My "No. 9," the novel little "runabout," which I shall describe in the succeeding chapter. The third of the new air-ships is

My "No. 10," which has been called "The Omnibus." Its gas capacity of 2010 cubic metres (nearly 80,000 cubic feet) makes its balloon greater in size and lifting power than even the racing "No. 7"; and should I, indeed, desire at any time to shift to it the latter's keel, all furnished with the racing motor and machinery, I might combine a very swift air craft capable of carrying myself, several aids and a large supply of both petroleum and ballast—not to speak of war munitions were the sudden need of a belligerent character.

The prime purpose of my "No. 10," however,

is well indicated in its name: "The Omnibus." Its keel, or, rather, keels, as I have fashioned them, are double—that is to say, hanging underneath its usual keel, in which my basket is situated, there is a passenger keel that holds three similar

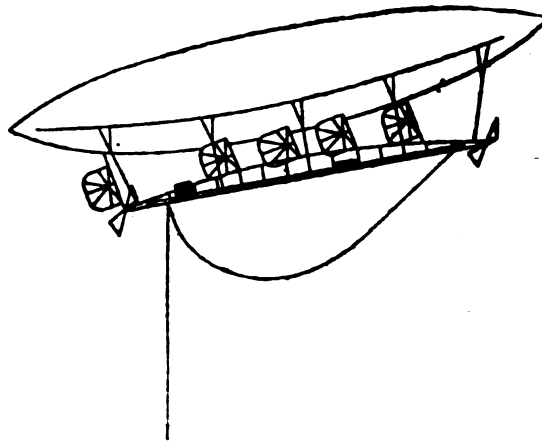
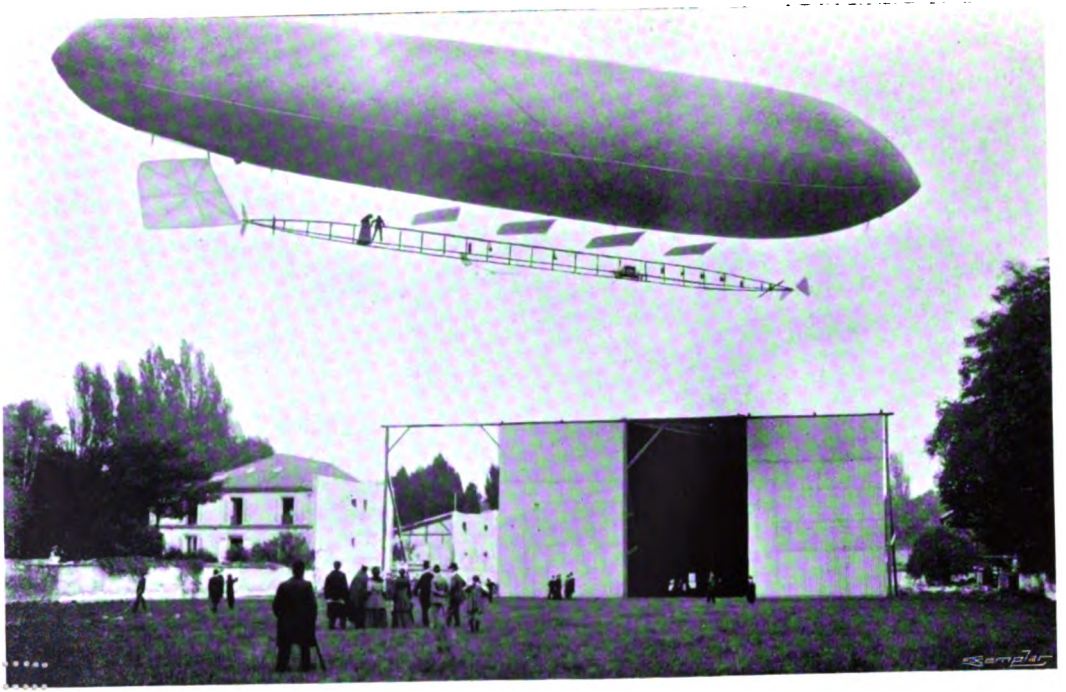


Fig. 13.—"No. 10" rising

baskets and a smaller basket for my aid. Each passenger basket is large enough to contain four passengers; and it is to carry such passengers that "The Omnibus" has been constructed.

Indeed, after mature reflection, it seemed to me that this must be the most practical and rapid way to popularise aerial navigation. In my other



"No. 10"

WITHOUT PASSENGER KEEL

air-ships I have shown that it is possible to mount and travel through the air on a prescribed course with no greater danger than one risks in any racing

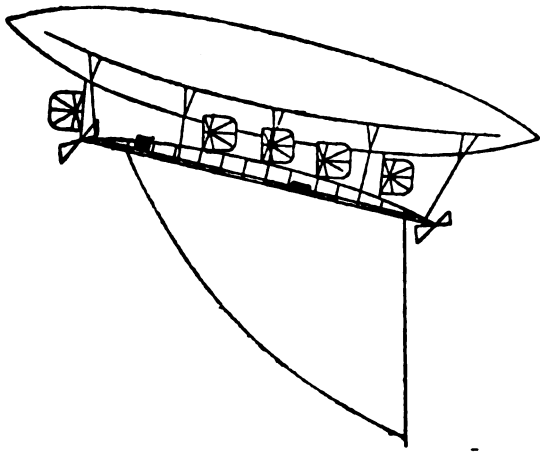


Fig. 14.—"No. 10" descending

automobile. In "The Omnibus" I shall demonstrate to the world that there are very many men —and women—possessed of sufficient confidence in the aerial idea to mount with me as passengers in the first of the air omnibuses of the future.

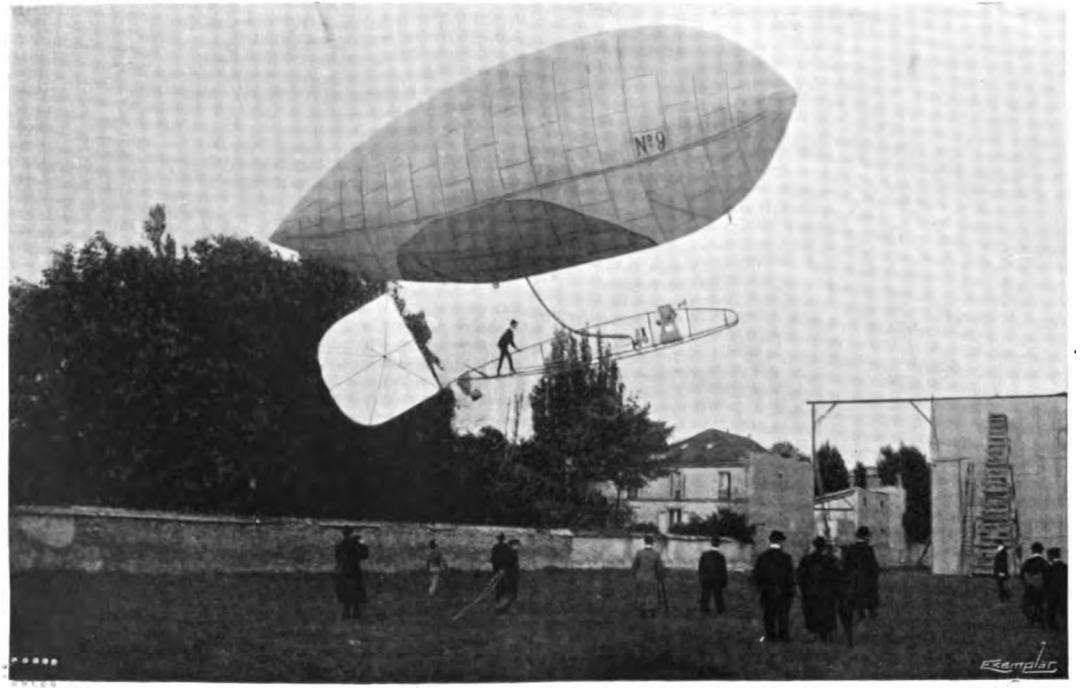
CHAPTER XXII

MY "NO. 9," THE LITTLE RUNABOUT

ONCE I was enamoured of high-power petroleum automobiles: they can go at express-train speed to any part of Europe, finding fuel in any village. "I can go to Moscow or Lisbon!" I said to myself. But when I discovered that I did not want to go to Moscow or to Lisbon the small and handy electric runabout in which I do my errands about Paris and the Bois proved more satisfactory.

Speaking from the standpoint of my pleasure and convenience as a Parisian my air-ship experience has been similar. When the balloon and motor of my 60 horse-power "No. 7" were completed I said to myself:

"I can race any air-ship that is likely to be built!" But when I found that, in spite of the forfeits I paid into the Aéro Club's treasury, there was no one ready to race with me I determined to build a small air-ship runabout for my pleasure and convenience only. In it I would pass the



"SANTOS-DUMONT No. 9"

time while waiting for the future to bring forth competitions worthy of my race craft.

So I built my "No. 9," the smallest of possible dirigibles, yet very practical indeed. As originally constructed, its balloon's capacity was but 220 cubic metres (7770 cubic feet), permitting me to take up less than 30 kilogrammes (66 lbs.) of ballast—and thus I navigated it for weeks, without inconvenience. Even when I enlarged its balloon to 261 cubic metres (9218 cubic feet) the balloon of my "No. 6," in which I won the Deutsch prize, would have made almost three of it, while that of my "Omnibus" is fully eight times its size. As I have already stated, its 8 horse-power Clement motor weighs but 12 kilogrammes (26½ lbs.). With such a motor one cannot expect great speed; nevertheless, this handy little runabout takes me over the Bois at between 20 and 25 kilometres (12 and 15 miles) per hour, and this notwithstanding its egg-shaped form (Fig. 15), which would seemingly be little calculated for cutting the air. Indeed, to make it respond promptly to the rudder, I drive it thick end first.

I have said that, as it was originally proportioned, the balloon of this smallest of possible

dirigibles permitted me to take up less than 30 kilogrammes (66 lbs.) of ballast. As now enlarged its lifting power is greater; but when account is taken of my own weight and the weight of keel, motor, screw, and machinery, the whole system becomes neither lighter nor heavier

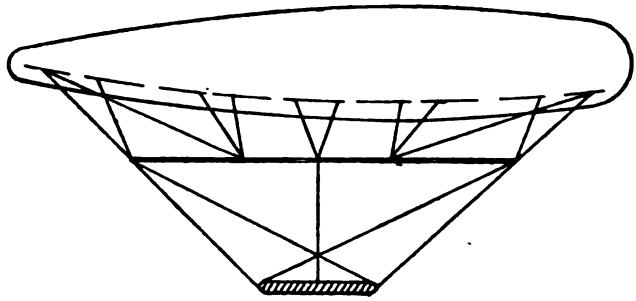
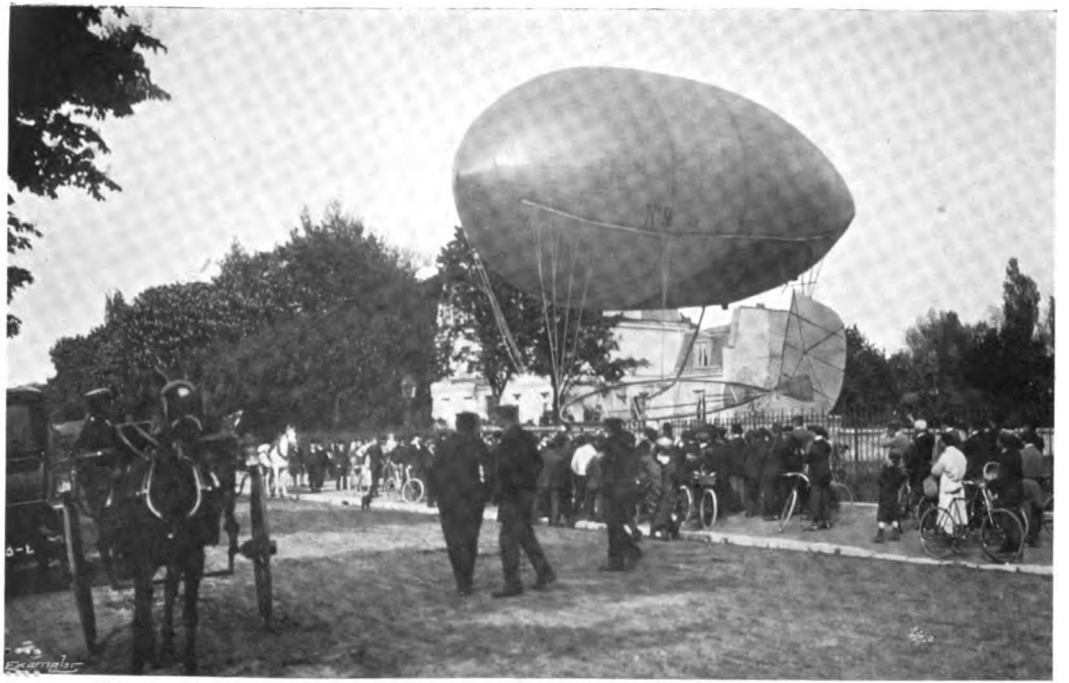


Fig. 15

than the surrounding atmosphere when I have loaded it with 60 kilogrammes (132 lbs.) of ballast; and it is just in this connection that it will be easiest to explain why I have called this little air-ship very practical. On Monday, 29th June 1903, I landed with it on the grounds of the Aéro Club at St Cloud in the midst of six inflated spherical balloons. After a short call I started off again.

"Can we not give you some gas?" politely asked my fellow-clubmen.



"No. 9." SHOWING RELATIVE SIZE

"You saw me coming all the way from Neuilly," I replied; "did I throw out any ballast?"

"You threw out no ballast," they admitted.

"Then why should I be in need of gas?"

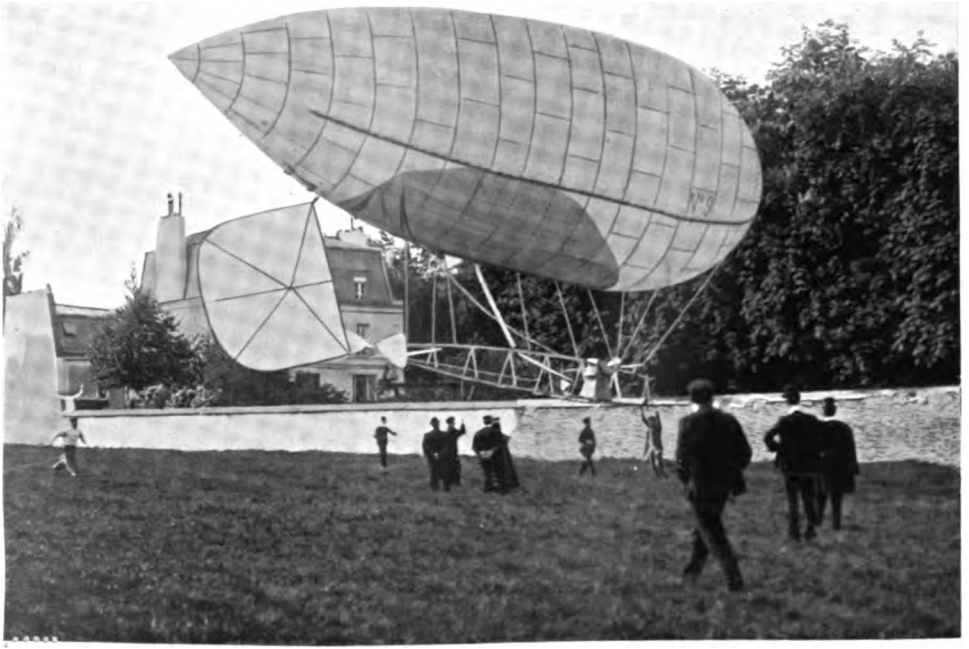
As a matter of scientific curiosity I may relate that I did not either lose or sacrifice a cubic foot of gas or a single pound of ballast that whole afternoon—nor has that experience been at all exceptional in the very practical little "No. 9" or even in its predecessors. It will be remembered that on the day succeeding the winning of the Deutsch prize my chief mechanician found that the balloon of my "No. 6" would take no gas because none had been lost.

After leaving my fellow-clubmen at St Cloud that afternoon I made a typically practical trip. To go from Neuilly St James to the Aéro Club's grounds I had already passed the Seine. Now, crossing it again, I made the café-restaurant of "The Cascade," where I stopped for refreshments. It was by this time 5 P.M. Not wishing to return yet to my station I crossed the Seine for a third time and went in a straight course as close to the great fort of Mount Valerien as delicacy permitted. Then, returning, I traversed the river once again and came to earth in my own grounds at Neuilly.

During the whole trip my greatest altitude was 105 metres (346 feet). Taking into consideration that my guide rope hangs 40 metres (132 feet) below me, and that the tops of the Bois trees extend up some 20 metres (70 feet) from the ground, this extreme altitude left me but 40 metres (140 feet) of clear space for vertical manœuvring.

It was enough; and the proof of it is that I do not go higher on these trips of pleasure and experiment. Indeed, when I hear of dirigibles going up 400 metres (1300 feet) in the air without some special justifying object I am filled with amazement. As I have already explained, the place of the dirigible is, normally, in low altitudes; and the ideal is to guide-rope on a sufficiently low course to be left free from vertical manœuvring. This is what M. Armengaud, *Jeune*, referred to in his learned inaugural discourse delivered before the Société Française de Navigation Aérienne in 1901, when he advised me to quit the Mediterranean and go guide-roping over great plains like that of La Beauce.

It is not necessary to go to the plain of La Beauce. One can guide-rope even in the centre of



"No. 9" JUMPING MY WALL

Paris if one goes about it at the proper moment. I have done it.

I have guide-roped round the Arc de Triomphe and down the Avenue des Champs Elysées at as low an altitude as the house-tops on either side, fearing no ill and finding no difficulty. My first flight of this kind occurred when I sought for the first time to land in my "No. 9" in front of my own house door, at the corner of the Avenue des Champs Elysées and the Rue Washington, on Tuesday, 23rd June 1903.

Knowing that the feat must be accomplished at an hour when the imposing pleasure promenade of Paris would be least encumbered, I had instructed my men to sleep through the early part of the night in the air-ship station at Neuilly St James so as to be able to have the "No. 9" ready for an early start at dawn. I myself rose at 2 A.M., and in my handy electric automobile arrived at the station while it was yet dark. The men still slept. I climbed the wall, waked them, and succeeded in quitting the earth on my first diagonally upward course over the wall and above the River Seine before the day had broken. Turning to the left, I made my way across the Bois, picking out

the open spaces so as to guide-rope as much as possible.

When I came to trees I jumped over them. So, navigating through the cool air of the delicious dawn, I reached the Porte Dauphine and the beginning of the broad Avenue du Bois de Boulogne, which leads directly to the Arc de Triomphe. This carriage promenade of Tout-Paris was empty.

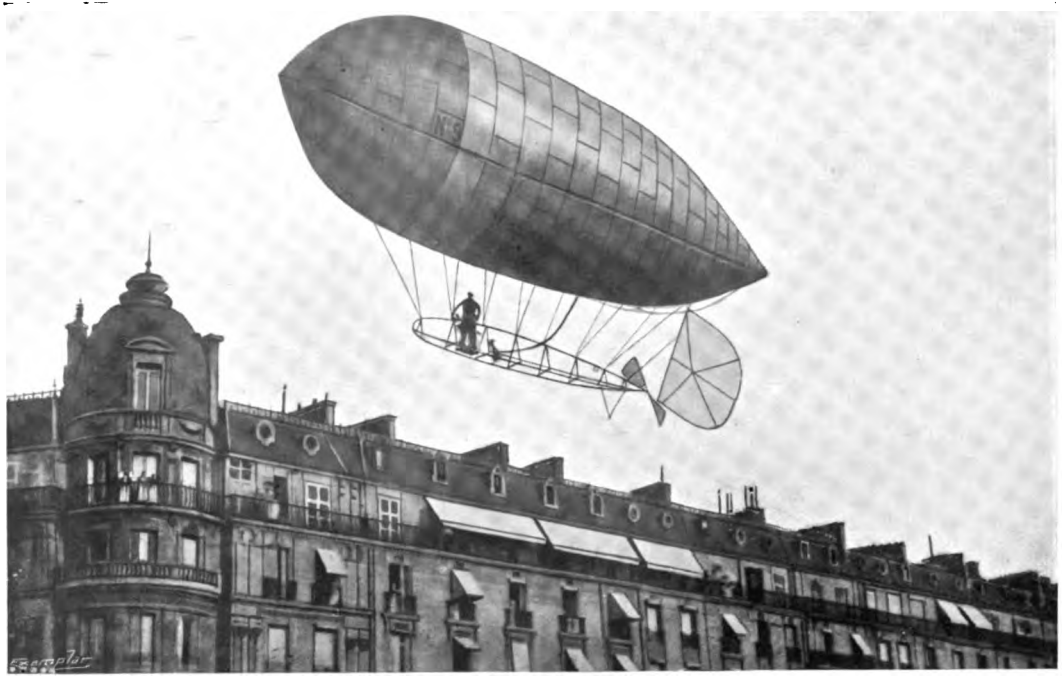
"I will guide-rope up the avenue of the Bois," I said to myself gleefully.

What this means you will perceive when I recall that my guide-rope's length is barely 40 metres (132 feet), and that one guide-ropes best with at least 20 metres (66 feet) of it trailing along the ground. Thus at times I went lower than the roofs of the houses on each side. I call this practical air-ship navigation because:

(*a*) It leaves the aerial navigator free to steer his course without pitching and without care or effort to maintain his steady altitude.

(*b*) It can be done with absolute safety from falling, not only to the navigator, but also to the air-ship—a consideration not without its merit when the cost, both of repairs and hydrogen gas, is taken into count; and

(*c*) When the wind is against one—as it was



"No. 9." GUIDE-ROPING ON A LEVEL WITH THE HOUSETOPS

on this occasion—one finds less of it in these low altitudes.

So I guide-roped up the avenue of the Bois. So, some day, will explorers guide-rope to the North Pole from their ice-locked steamship after it has reached its farthest point north. Guide-roping over the ice pack, they will make the very few hundreds of miles to the Pole at the rate of from 60 to 80 kilometres (40 to 50 miles) per hour. Even at the rate of 50 kilometres (30 miles), the trip to the Pole and back to the ship could be taken between breakfast and supper time. I do not say that they will land the first time at the Pole, but they will circle round about the spot, take observations, and return . . . for supper.

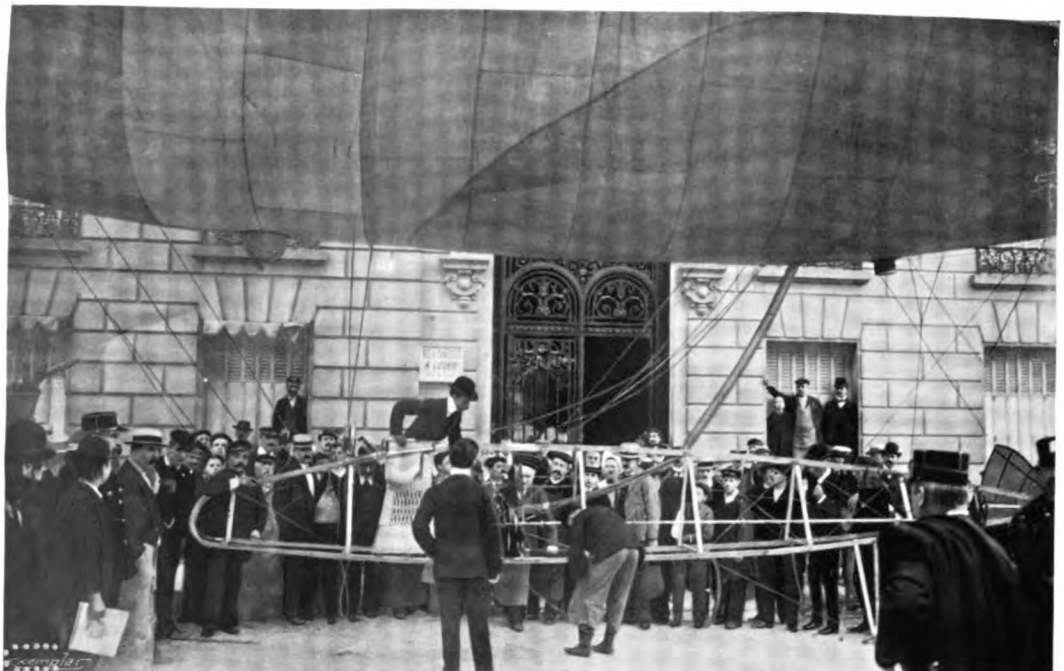
I might have guide-roped under the Arc de Triomphe had I thought myself worthy. Instead, I rounded the national monument to the right, as the law directs. Naturally, I had intended to go on straight down the Avenue des Champs Elysées, but here I met a difficulty. All the avenues meeting at the great "Star" look alike from the air-ship. Also, they look narrow. I was surprised and confused for a moment, and it was only by looking back to note the

situation of the Arc that I could find my avenue.

Like that of the Bois, it was deserted. Far down its length I saw a solitary cab. As I guide-roped along it to my house at the corner of the Rue Washington I thought of the time, sure to come, when the owners of handy little air-ships will not be obliged to land in the street, but will have their guide ropes caught by their domestics on their own roof gardens. But such roof gardens must be broad and unencumbered.

So I reached my corner, to which I pointed my stem, and descended very gently. Two servants caught, steadied, and held the air-ship, while I mounted to my apartment for a cup of coffee. From my round bay window at the corner I looked down upon the air-ship. Were I to receive the municipal permission it would not be difficult to build an ornamental landing-stage out from that window.

Projects like these will constitute work for the future. Meanwhile the aerial idea is making progress. A small boy of seven years of age has mounted with me in the "No. 9," and a charming young lady has actually navigated it alone for something like a mile. The boy will surely make



"No. 9." M. SANTOS-DUMONT LANDS AT HIS OWN DOOR

an air-ship captain if he gives his mind to it. The occasion was the children's *fête* at Bagatelle 26th June 1903. Descending among them in the "No. 9," I asked:

"Does any little boy want to go up?"

Such were the confidence and courage of young France and America that instantly I had to choose among a dozen volunteers. I took the nearest to me.

"Are you not afraid?" I asked Clarkson Potter as the air-ship rose.

"Not a bit," he answered. The cruise of the "No. 9" on this occasion was, naturally, a short one; but the other, in which the first woman to mount, accompanied or unaccompanied, in any air-ship, actually mounted alone and drove the "No. 9" free from all human contact with its guide rope for a distance of considerably over a kilometre (half-mile), is worthy of preservation in the annals of aerial navigation.

The heroine, a very beautiful young Cuban lady, well known in New York society, having visited my station with her friends on several occasions, confessed an extraordinary desire to navigate the air-ship.

"Would you have the courage to be taken up

in the free air-ship with no one holding its guide rope?" I asked. "Mademoiselle, I thank you for the confidence."

"Oh, no," she said; "I do not want to be taken up. I want to go up alone and navigate it freely, as you do."

I think that the simple fact that I consented on condition that she would take a few lessons in the handling of the motor and machinery speaks eloquently in favour of my own confidence in the "No. 9." She had three such lessons, and then on 29th June 1908, a date that will be memorable in the Fasti of dirigible ballooning, rising from my station grounds in the smallest of possible dirigibles, she cried: "Let go all!"

From my station at Neuilly St James she guide-roped to Bagatelle. The guide rope, trailing some 10 metres (30 feet), gave her an altitude and equilibrium that never varied. I will not say that no one ran along beside the dragging guide rope, but, certainly, no one touched it until the termination of the cruise at Bagatelle, when the moment had arrived to pull down the intrepid girl navigator.

CHAPTER XXIII

THE AIR-SHIP IN WAR

On Saturday morning, 11th July 1908, at about 10 A.M., the wind blowing at the time in gusts, I accepted a wager to go to luncheon at the sylvan restaurant of "The Cascade" in my little "No. 9" air-ship. While the "No. 9," with its egg-shaped balloon, and motor of but 8 horse-power, was not built for speed—or, what amounts to the same thing, for battling with the wind—I thought that I could do it. Reaching my station at Neuilly St James at about 11.30 A.M. I had the little craft brought out and carefully weighed and balanced. It was in perfect condition, having lost none of its gas from the previous day. At 11.50 I started off. Fortunately, the wind came to me head-on as I steered for "The Cascade." My progress was not rapid, but I, nevertheless, met my friends on the lawn of that café-restaurant of the Bois de Boulogne at 12.30 noon. We took our luncheon, and I

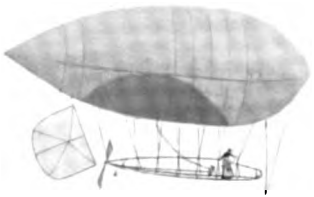
was preparing to depart when began an adventure that may take me far.

As everybody knows, the restaurant of "The Cascade" is close to Longchamps. While we lunched, officers of the French army engaged in marking out the positions of the troops for the grand review of the 14th of July observed the air-ship on the lawn and came to inspect it.

"Shall you come to the review in it?" they asked me. The year previous there had been question of such a demonstration in presence of the army, but I had hesitated for reasons that may be readily divined. After the visit of the King of England I was asked on every hand why I had not brought out the air-ship in his honour, and the same questions had arisen in anticipation of the visit of the King of Italy, who had been expected to be present at this review.

I answered the officers that I could not make up my mind; that I was not sure how such an apparition would be viewed; and that my little "No. 9"—the only one of my fleet actually "in commission"—not being built for battling with high winds I could not be sure to keep an engagement in it.

"Come and choose a place to land," they said;



"No. 9." OVER BOIS DE BOULOGNE

"we will mark it out for you in any case." And, as I continued to insist on my uncertainty of being present, they very courteously picked out and marked a place for me themselves, opposite the spot to be occupied by the President of the Republic, in order that M. Loubet and his staff might have a perfect view of the airship's evolutions.

"You will come if you can," the officers said. "You need not fear to make such a provisional engagement, for you have already given your proofs."

I hope I shall not be misunderstood when I say that it may be possible that those superior officers did good work for their army and country that morning—because, in order to begin, one must make a beginning—and I should scarcely have ventured to the review without some kind of invitation.

Venturing to the review, as I did in consequence, a whole train of events followed.

In the early morning of 14th July 1903, as the "No. 9" was weighed and balanced, I was nervous lest some unforeseen thing might happen to it in my very grounds. One is often thus on great occasions, and I did not seek to conceal it from

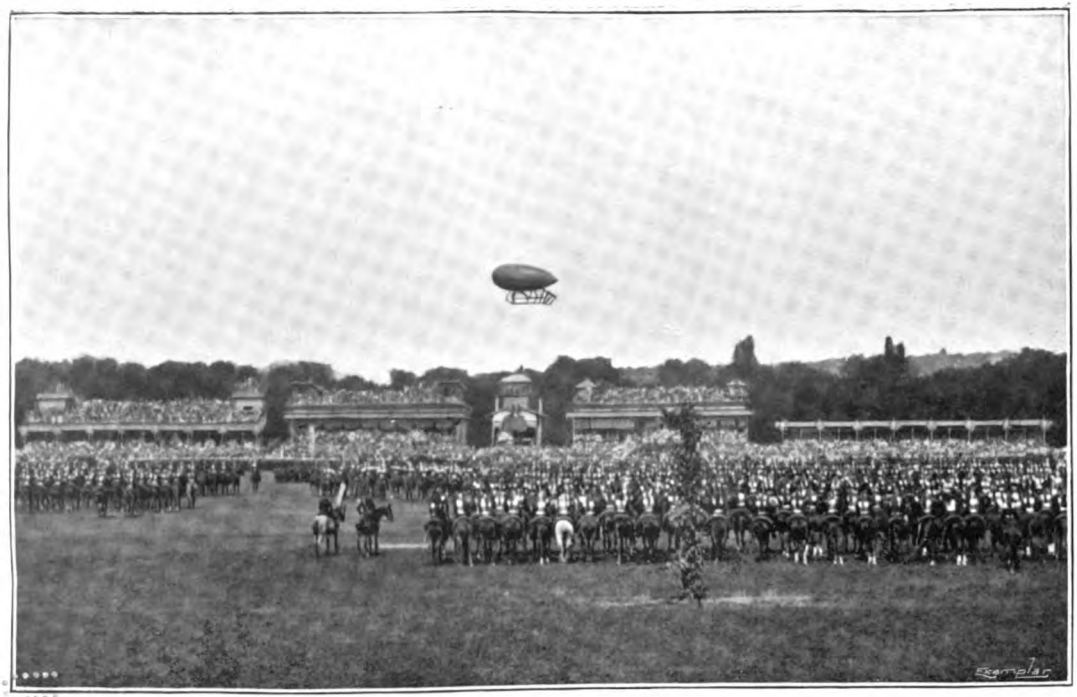
myself that this—the first presentation of an air-ship to any army—would be a great occasion.

On ordinary days I never hesitate to mount from my grounds, over the stone wall and the river, and so on to Bagatelle. This morning I had the "No. 9" towed to the railing of Bagatelle by means of its guide rope.

At 8.30 A.M. I called: "Let go all!" Rising, I found my level course at an altitude of less than 100 metres (330 feet), and in a few moments was circling and manœuvring above the heads of the soldiers nearest to me. Thence I passed over Longchamps, and arriving opposite the president I fired a salute of twenty-one blank revolver cartridges.

I did not take the place marked out for me. Fearing to disturb the good order of the review by prolonging an unusual sight I made my evolutions in the presence of the army last, all told, less than ten minutes. After this I steered for the polo grounds, where I was congratulated by numbers of my friends.

These congratulations I found the next day repeated in the Paris papers, together with conjectures of all kinds concerning the use of the air-ship in war. The superior officers who came



"No. 9." AT MILITARY REVIEW, JULY 14, 1903

to me at "The Cascade" that morning had said: "It is practical, and will have to be taken account of in war."

"I am entirely at your service!" had been my answer at the time; and now, under these influences, I sat down and wrote to the Minister of War, offering, in case of hostilities with any country save those of the two Americas, to put my aerial fleet at the disposition of the Government of the Republic.

In doing this I merely put into formal written words the offer which I certainly should feel bound to make in case of the breaking out of such hostilities at any future time during my residence in France. It is in France that I have met with all my encouragement; in France and with French material I have made all my experiments; and the mass of my friends are French. I excepted the two Americas because I am an American, and I added that in the impossible case of a war between France and Brazil I should feel bound to volunteer my services to the land of my birth and citizenship.

A few days later I received the following letter from the French Minister of War:—

REPUBLIQUE FRANCAISE,
PARIS, *le* 19 *Juillet* 1903.

MINISTERE DE LA GUERRE,
CABINET DU MINISTRE.

MONSIEUR,—During the Review of the Fourteenth of July, I had remarked and admired the ease and security with which the balloon you were steering made its evolutions. It was impossible not to acknowledge the progress which you have given to aerial navigation. It seems that, thanks to you, such navigation must, henceforward, lend itself to practical applications, especially from the military point of view.

I consider that, in this respect, it may render very substantial services in time of war. I am very happy, therefore, to accept the offer which you make, of putting, in case of need, your aerial flotilla at the disposition of the Government of the Republic, and, in its name, I thank you for your gracious proposition, which shows your lively sympathy for France.

I have appointed Chief of Battalion Hirschauer, commanding the Battalion of Balloonists in the First Regiment of Engineers, to examine, in agreement with you, the dispositions to take for

putting the intentions you have manifested into execution. Lieutenant-Colonel Bourdeaux, Sous-Chef of my Cabinet, will also be associated with this superior officer, in order to keep me personally aware of the results of your joint labours.

Recevez, Monsieur, les assurances de ma considération la plus distinguée.

(Signed) GENERAL ANDRE.

A Monsieur Alberto Santos-Dumont.

On Friday, 31st July 1908, Commandant Hirschauer and Lieutenant-Colonel Bourdeaux spent the afternoon with me at my air-ship station at Neuilly St James, where I had my three newest air-ships—the racing "No. 7," the omnibus "No. 10," and the runabout "No. 9"—ready for their study. Briefly, I may say that the opinions expressed by the representatives of the Minister of War were so unreservedly favourable that a practical test of a novel character was decided to be made. Should the air-ship chosen pass successfully through it the result will be conclusive of its military value.

Now that these particular experiments are leaving my exclusively private control I will say no more of them than what has been already

published in the French press. The test will probably consist of an attempt to enter one of the French frontier towns, such as Belfort, or Nancy, on the same day that the air-ship leaves Paris. It will not, of course, be necessary to make the whole journey in the air-ship. A military railway waggon may be assigned to carry it, with its balloon uninflated, with tubes of hydrogen to fill it, and with all the necessary machinery and instruments arranged beside it. At some station a short distance from the town to be entered the waggon may be uncoupled from the train, and a sufficient number of soldiers accompanying the officers will unload the air-ship and its appliances, transport the whole to the nearest open space, and at once begin inflating the balloon. Within two hours from the time of quitting the train the air-ship may be ready for its flight to the interior of the technically-besieged town.

Such may be the outline of the task—a task presented imperiously to French balloonists by the events of 1870-1, and which all the devotion and science of the Tissandier brothers failed to accomplish. To-day the problem may be set with better hope of success. All the essential difficulties may be revived by the marking out of a hostile zone

around the town that must be entered; from beyond the outer edge of this zone, then, the air-ship will rise and take its flight—across it.

Will the air-ship be able to rise out of rifle range? I have always been the first to insist that the normal place of the air-ship is in low altitudes, and I shall have written this book to little purpose if I have not shown the reader the real dangers attending any *brusque* vertical mounting to considerable heights. For this we have the terrible Severo accident before our eyes. In particular, I have expressed astonishment at hearing of experimenters rising to these altitudes without adequate purpose in their early stages of experience with dirigible balloons. All this is very different, however, from a reasoned, cautious mounting, whose necessity has been foreseen and prepared for.

To keep out of rifle range the air-ship will but seldom be obliged to make these tremendous vertical leaps. Its navigator, even at a moderate altitude, will enjoy a very extended view of the surrounding country. Thus he will be able to perceive danger afar off, and take his precautions. Even in my little "No. 9," which carries only 60 kilogrammes (132 lbs.) of ballast, I could rise, materially aided by my shifting weights and pro-

peller, to great heights. If I have not done so it is because it would have served no useful purpose during a period of pleasure navigation, while it would but have added danger to experiments from which I have sought to eliminate all danger. Dangers like these are to be accepted only when a good cause justifies them.

The experiments above named are, of course, of a nature interesting warfare by land. I cannot abandon this topic, however, without referring to one unique maritime advantage of the air-ship. This is its navigator's ability to perceive bodies moving beneath the surface of the water. Cruising at the end of its guide rope, the air-ship will carry its navigator here and there at will at the right height above the waves. Any submarine boat, stealthily pursuing its course underneath them, will be beautifully visible to him, while from a warship's deck it would be quite invisible. This is a well-observed fact, and depends on certain optical laws. Thus, very curiously, the twentieth century air-ship must become from the beginning the great enemy of that other twentieth century marvel—the submarine boat—and not only its enemy but its master. For, while the submarine boat can do no harm to the air-ship, the latter,

having twice its speed, can cruise about to find it, follow all its movements, and signal them to the warships against which it is moving. Indeed, it may be able to destroy the submarine boat by sending down to it long arrows filled with dynamite, and capable of penetrating to depths underneath the waves impossible to gunnery from the decks of a warship.

CHAPTER XXIV

PARIS AS A CENTRE OF AIR-SHIP EXPERIMENTS

AFTER leaving Monte Carlo, in February 1902, I received many invitations from abroad to navigate my air-ships. In London, in particular, I was received with great friendliness by the Aéro Club of Great Britain, under whose auspices my "No. 6," fished from the bottom of the bay of Monaco, repaired and once again inflated, was exhibited at the Crystal Palace.

From St Louis, where the organisers of the Louisiana Purchase Centennial Exposition had already decided to make air-ship flights a feature of their World's Fair in 1904, I received an invitation to inspect the grounds, suggest a course, and confer with them on conditions. As it was officially announced that a sum of 200,000 dollars had been voted and set apart for prizes it might be expected that the emulation of air-ship experimenters would be well aroused.

Arriving at St Louis in the summer of 1902,

I at once saw that the splendid open spaces of the Exposition Grounds offered the best of race-courses. The prevailing idea at that moment in the minds of some of the authorities was to set a long course of many hundreds of miles—say, from St Louis to Chicago. This, I pointed out, would be impracticable, if only for the reason that the Exposition public would desire to see the flights from start to finish. I suggested that three great towers or flagstaffs be erected in the grounds at the corners of an equal-sided triangle. The comparatively short course around them—between 10 and 20 miles—would afford a decisive test of dirigibility no matter in what way the wind might blow; while as for speed, the necessary average might be increased 50 per cent. over that fixed for the Deutsch prize competition in Paris.

Such was my modest advice. I also thought that, out of the appropriation of 200,000 dollars (1,000,000 francs), a grand prize for dirigible aerostation of 100,000 dollars should be offered; only by means of such an inducement, it seemed to me, could the necessary emulation among air-ship experimenters be aroused.

While never seeking to make profit from my air-ships, I have always offered to compete for

prizes. While in London, and again in New York, both before and after my St Louis visit, competitions with prize sanctions were suggested to me for immediate effort. I accepted all of them to this point, that I had my air-ships brought to the spot at considerable cost and effort, and had the prize funds been deposited I would have done my best to win them. Such deposits failing, I, in each case, returned to my home in Paris to continue my experiments in my own way, awaiting the great competition of St Louis.

Prize or no prize, I must work, and I shall always work in this my chosen field of aerostation. For this my place is Paris, where the public, in particular the kindly and enthusiastic populace, both knows and trusts me. Here, in Paris, I go up for my own pleasure day by day, as my reward for long and costly experiment.

In England and America it is quite different. When I take my air-ships and my employees to those countries, build my own balloon house, furnish my own gas plant, and risk breaking machines that cost more than any automobile, I want it to be done with a settled aim.

I say that I want it to be done with a settled aim, so that, if I fulfil the aim, I may no longer

be criticised, at least on that particular head. Otherwise I might go to the moon and back and yet accomplish nothing in the estimation of my critics and—though, perhaps, to a less extent—in the mind of the public which they sway.

Why have I sought to win prizes? Because the most rational consecration of such effort and its fulfilment is found in a serious money prize. The mind of the public makes the obvious connection. When a valuable prize is handed over it concludes that something has been done to win it.

To win such prizes, then, I waited long in London and New York; but, as they never passed from words to deeds, after having enjoyed myself very thoroughly, both socially and as a tourist, I returned to my work and pleasure in the Paris which I call my home.

And really, after all is said and done, there is no place like Paris for air-ship experiments. Nowhere else can the experimenter depend on the municipal and State authorities to be so liberal.

Take the development of automobilism as an example. It is universally admitted, I imagine, that this great and peculiarly French industry could not have developed without the speed licence

which the French authorities have wide-mindedly permitted. In spite of the most powerful social and industrial influences, and in spite of it being England's turn to offer hospitality to the James Gordon Bennett cup race of 1903, the English automobilists were not allowed to put their splendid roads out of the public use for its accommodation for a single day. So the great event had to come off in Ireland.

In France, and in France only, are not only the authorities, but the great mass of citizens, so much alive to their advantage in the development of this national industry that, day by day, year in and year out, they permit ten thousand automobiles to go tearing through the highroads at a really dangerous speed. In Paris, in particular, one sees a "scorching" average in its great Park and its very avenues and streets that causes Londoners and tourists from New York to stand aghast.

In this same order of ideas I may here state that, in spite of the tragic air-ship accidents of 1902, I have never once been limited or in any way impeded in the course of my experiments by the Parisian authorities; while as for the public, no matter where I land with an air-ship—in the

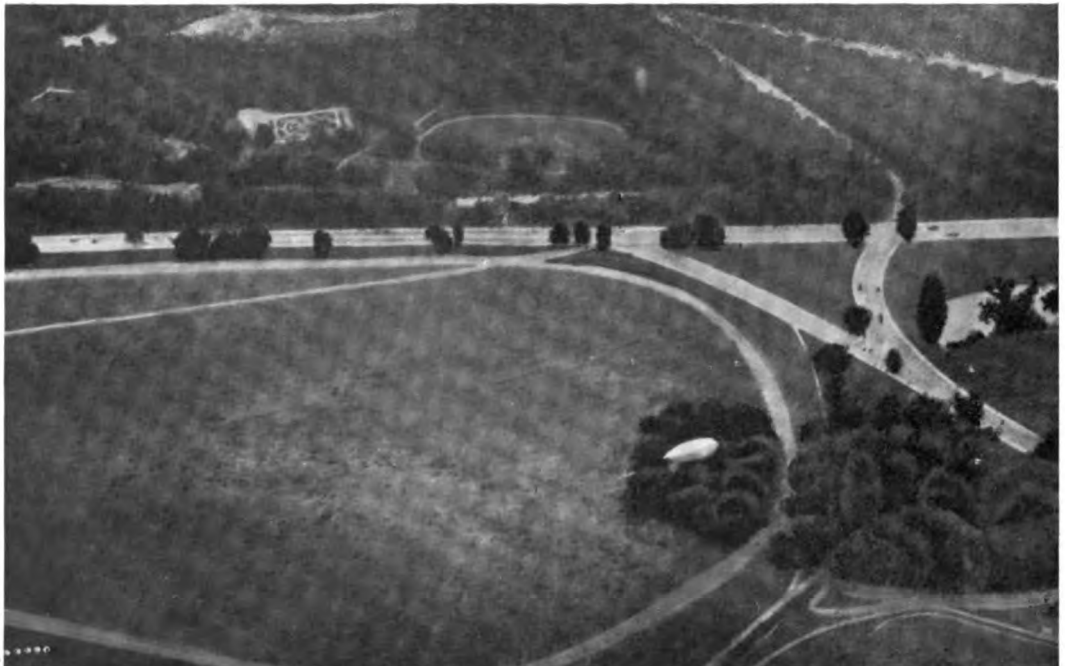
country roads of the suburbs, in private gardens, even of great villas, in the avenues and parks and public places of the capital—I meet with unvarying friendly aid, protection, and enthusiasm.

From that first memorable day when the big boys flying their kites over Bagatelle seized my guide rope and saved me from an ugly fall as promptly and intelligently as they had seized the idea of pulling me against the wind, to the critical moment on that summer day in 1901 when, in my first trial for the Deutsch prize, I descended to repair my rudder, and good-natured working-men found me a ladder in less time than it takes me to write the words—and on down to the present moment, when I take my pleasure in the Bois in my small "No. 9"—I have had nothing but unvarying friendliness from the intelligent Parisian populace.

I need not say that it is a great thing for an air-ship experimenter thus to have the confidence and friendly aid of a whole population. Over certain European frontiers spherical balloons have even been shot at. And I have often wondered what kind of a reception one of my air-ships would meet with in the country districts of England itself.

For these reasons, and a hundred others, I consider that my air-ship's home, like my own, is in Paris. As a boy, in Brazil, my heart turned to the City of Light, above which in 1783 the first Montgolfier had been sent up; where the first of the world's aeronauts had made his first ascension; where the first hydrogen balloon had been set loose; where first an air-ship had been made to navigate the air with its steam-engine, screw propeller, and rudder.

As a youth I made my own first balloon ascension from Paris. In Paris I have found balloon constructors, motor makers, and machinists possessed not only of skill but of patience. In Paris I made all my first experiments. In Paris I won the Deutsch prize in the first dirigible to do a task against a time limit. And, now that I have not only what I call my racing air-ship but a little "runabout," in which to take my pleasure over the trees of the Bois, it is in Paris that I am enjoying my reward in it as—what I was once called reproachfully—an "aerostatic sportsman!"



"No. 9." SEEN FROM CAPTIVE BALLOON, JUNE 11, 1903

CONCLUDING FABLE

MORE REASONING OF CHILDREN

DURING these years Luis and Pedro, the ingenious country boys whom we found reasoning of mechanical inventions in the Introductory Fable of this book, have spent some time in Paris. They were present at the winning of the Deutsch prize of aerial navigation; they spent the winter of 1901-2 at Monte Carlo; had good places at the review of the 14th July 1903; and have broadened their education by the sedulous reading of scientific weeklies and the daily newspapers. Now they are preparing to return to Brazil.

The other day, seated on a café terrace of the Bois de Boulogne, they chatted of the problem of aerial navigation.

"These tentatives with dirigible balloons, so called, can bring us no nearer to its solution," said Pedro. "Look you, they are filled with a substance—hydrogen—fourteen times lighter than the medium in which it floats—the atmosphere.

It would be just as possible to force a tallow candle through a brick wall!"

"Pedro," said Luis, "do you remember your objections to my waggon wheels?"

. . . .

"To the locomotive engine?"

. . . .

"To the steamboat?"

"Our only hope to navigate the air," continued Pedro, "must, in the nature of things, be found in devices heavier than the air—in flying machines or aeroplanes. Reason by analogy. Look at the bird. . . ."

"Once you desired me to look at the fish," said Luis. "You said the steamboat ought to wriggle through the water. . . ."

"Do be serious, Luis," said Pedro in conclusive tones. "Exercise common-sense. Does man fly? No. Does the bird fly? Yes. Then, if man would fly, let him imitate the bird. Nature has made the bird. Nature never goes wrong."